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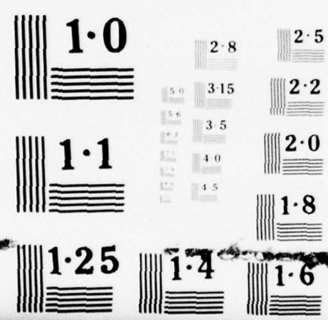
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AN ANALYSIS OF LANDSAT SYSTEMS FOR CARTOGRAPHIC AND TERRAIN INFORMATION

(REPORT NO. 9 IN THE ETL SERIES ON REMOTE SENSING)

JUNE 1977

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SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

REPORT DOCUMENTATION PAGE		READ INSTRUCTIONS BEFORE COMPLETING FORM
1. REPORT NUMBER ETL-0103	2. GOVT ACCESSION NO.	3. RECIPIENT'S CATALOG NUMBER
4. TITLE (and Subtitle) AN ANALYSIS OF LANDSAT SYSTEMS FOR CARTOGRAPHIC AND TERRAIN INFORMATION (Report No. 9 in the ETL Series on Remote Sensing)		5. TYPE OF REPORT & PERIOD COVERED Technical Report (Aug — Dec 76)
		6. PERFORMING ORG. REPORT NUMBER NA
7. AUTHOR(s) Theodore C. Vogel		8. CONTRACT OR GRANT NUMBER(s) NA
9. PERFORMING ORGANIZATION NAME AND ADDRESS U.S. Army Engineer Topographic Laboratories Fort Belvoir, Virginia 22060		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS 4A762707A855 T3/0018
11. CONTROLLING OFFICE NAME AND ADDRESS U.S. Army Engineer Topographic Laboratories Fort Belvoir, Virginia 22060		12. REPORT DATE June 1977
		13. NUMBER OF PAGES ~~58~~ 61
14. MONITORING AGENCY NAME & ADDRESS (if different from Controlling Office) NA		15. SECURITY CLASS. (of this report) Unclassified
		15a. DECLASSIFICATION/DOWNGRADING SCHEDULE NA

16. DISTRIBUTION STATEMENT (of this Report)

Approved for public release; distribution unlimited.

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY NOTES

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Remote Sensing
Aerial Imagery
Photo Interpretation
Multispectral Imagery
Cartography
Terrain Analysis
Thematic Mapping

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

The scientific and technical literature is reviewed to analyze the capabilities of LANDSAT Systems 1, 2, 3, and 4 for hydrographic, topographic, planimetric, and thematic map compilation. The systems capabilities were analyzed according to the following qualitative code for a selected list of map and chart requirements: 0 - Not detectable, the map element cannot be discerned or located from either type of LANDSAT data; 1 - Detectable, map element can be detected but not identified from the type of LANDSAT data

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Item 20. (continued):

cont.

indicated; 2 - Identifiable, map element can be detected and recognized as a particular type of feature from the LANDSAT data indicated, e.g. road, canal, etc., collateral information may be required to reach this analysis level; 3 - Classifiable, LANDSAT data, with the use of all available collateral information, can provide the information required for the map element including all required measurements, e.g. width, length, and areas. It was concluded that LANDSAT 1, 2, 3 MSS data is compatible with National Map Accuracy Standards and can be used to update the map elements on map scales 1:1,000,000 through 1:250,000, although many of the cultural, hydrographic, and botanical elements may be unclassifiable. The improved systems capabilities of LANDSAT 4 may provide a method for updating map scales 1:1,000,000 through 1:50,000. However, many of the required cultural and hydrographic map elements may remain unclassifiable even with the Thematic Mapper system.

PREFACE

The authority for conducting this investigation is contained in project 4A762707A855, Task T3, entitled "Military Geographic Analysis Technology."

This analysis was conducted in the Geographic Information Systems Division of the Geographic Sciences Laboratory. The author wishes to acknowledge with sincere appreciation Ms. N. E. Kothe, Chief, Scientific and Technical Information Center, for her aid in locating and obtaining the technical literature.

USAETL REPORT
IN THE REMOTE SENSING SERIES

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INTRODUCTION

One of the more valid methods of analyzing a remote sensor system for cartographic and terrain analysis would be to design a test plan that would consider all of the variables associated with the acquisition and interpretation of imagery produced by the system. By necessity, the test plan would include such system and acquisition parameters as resolution, spectral response, geometric accuracy, sun angle, altitude, geographic region, land use practices, type of terrain, and season. To be effective, the image analysis variables would have to include human, automated, and an interactive human-automated method of analysis. Inherent in each of the image variables is another series of variables that must be controlled. Probably the most important of these variables is the experience level of the image interpreters and the amount and type of collateral material employed in the interpretation process. These two variables are important because they determine the amount and accuracy of information that can be obtained from the aerial image.

Unfortunately, this test plan is expensive, difficult to conduct, and requires a considerable amount of time. Another method of analyzing a remote sensor system is to review and evaluate the scientific and technical literature; this method was used in preparing this report. Although it is more subjective in nature, this method provides a means of determining the broad capabilities of a sensor system. It is cost-effective and can be completed in a short time.

Purpose. The purpose of this report is to determine the capabilities of LANDSAT Systems 1 and 2* for terrain analysis and compilation of thematic, topographic, planimetric, and hydrographic maps. In addition, LANDSAT Systems 3 and 4 will be analyzed to determine the effect of increased capabilities.

Scope. This report reviews the technical and scientific literature and a selected list of Department of Defense (DOD) map and chart requirements to determine the effectiveness of existing LANDSAT Systems 1 and 2 for providing the information required to meet the specific needs of DOD for terrain and cartographic information. In addition, the analysis also attempts (based on the literature review and a knowledge of remote sensing) to determine the value of the increased capabilities of future LANDSAT Systems 3 and 4. Owing to the failure of the Return Beam Vidicon (RBV) in LANDSAT Systems 1 and 2, only the Multispectral Scanner System (MSS) of these satellites are considered in this report.

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*ERTS Systems A, B, C, and D were redesignated LANDSAT Systems 1, 2, 3, and 4 by NASA in 1975.

METHOD

Analysis Procedure. The qualitative procedure used in this report to analyze the capabilities of LANDSAT Systems 1 and 2 for cartographic and terrain data were based, primarily, on a review of the technical literature and the Department of Defense map and chart requirements. However, an additional number of map elements or terrain features were added to provide a more complete list for the ETL thematic mapping effort. An actual comparative analysis of either the LANDSAT imagery or digital data was excluded from this report because of the difficulty and time involved in collecting representative samples of these data. The information acquired through review of the literature was tempered with the experience and background of ETL personnel before each analysis was made. Admittedly, this analysis procedure is subjective in nature, but an objective or quantitative technique for determining the capabilities of the remote sensing systems employed in a program as large and complex as the NASA Earth Resources Satellite (ERTS) program does not exist.

Map Requirements. The DOD through the Defense Mapping Agency (DMA) periodically publish the specifications and requirements for the maps and charts used by the various commands and agencies within this Department.[1,2,3,4] These specifications, along with the National Standard Map Accuracy Requirements, dictate not only what type of map will be produced but also what terrain and cultural features will be depicted and at what level of accuracy the maps will be produced.

The National Standard Map Accuracy Requirements provide for three levels of accuracy. The Class A Standards, summarized in table 1 by map scale, state that 90 percent of all well defined features will be located within 0.02 inch (.50 millimeters) horizontal distance (map scale) and a vertical distance of one-half of the contour interval. The accuracy limits of Class B and C are somewhat larger and are not considered in this analysis. Class B and C maps, however, would probably provide suitable accuracy limits for 90 percent of civilian and military users.

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[1] Department of Defense, TPC TM S-1 Map Specifications, October 1971.

[2] Department of Defense, Defense Mapping Agency, Production Specifications for Joint Operations Graphics (3rd Edition) Series 1501 and Series 1501 Air Scale 1:250,000, July 1972.

[3] Department of Defense, Defense Mapping Agency, Production Specifications (Guidelines) for Off-Line Digital Data Base, 1974.

[4] Department of Defense, DOD Production Specifications for Operational Navigation Chart (4th Edition) Scale 1:1,000,000, August 1968.

Table 1. Summary of Class A
National Standard Map Accuracy Requirements

Scale	Accuracy Horizontal (meters)	Vertical (meters)*
1:1,000,000	500	30-60
1:250,000	125	30-50
1:100,000	50	20-40
1:50,000	25	5-10
1:25,000	12.5	5
1:12,500	6.25	1-5

*The contour interval is dependent on map scale and type of terrain to be mapped.

In general, however, the map and chart requirements as specified by the DOD provide the cartographer with a considerable amount of freedom in determining the specific terrain and cultural features for a chart or map. For example, when there are many lakes in an area, the cartographer is not required to locate all of the lakes on the map. He has the option of placing only a few of the lakes on the map with a notation that informs the user that there are numerous lakes in that specific location.

In addition to the leniency provided the cartographer in the amount of information and the minimum size of the feature that he places on a map, he also has a certain amount of leeway in the accuracy with which he locates each feature. In instances where a double railroad track and a 4-lane highway parallel a lake shore, the cartographer will often have to falsify the true map distance in order to place the proper symbolization on the map. To provide the user with a product that contains as much information as possible without causing confusion, the cartographer has to have the degree of freedom provided in the specifications. This freedom, however, does result in a certain amount of inaccuracy in the final product.

The seven types of maps or charts employed in this analysis were selected to represent the range of graphics and cartographic requirements needed by DOD. These maps vary in scale from the very large scale Military City Map (1:12,500) to the small scale Operational Navigation Chart (1:1,000,000).

Military City Map. This map is usually prepared at a scale of 1:12,500, but if more detailed information is required, it can be prepared at scales as large as 1:5,000. The city map is probably the most detailed map produced by the DOD.

Topographic Map. The major difference between the topographic and planimetric maps is that the topographic map provides both vertical and horizontal positions of the terrain and terrain features. The maps can be prepared at a number of scales with the amount of natural and manmade features commensurate with scale.

Joint Operations Graphic. This map is always produced at a scale of 1:250,000 and is considered to be a medium scale topographic map. It is similar in format to the standard 1:50,000 topographic map.

Digital Radar Landmass Simulator. These requirements are for the formation of a cartographic data base that has three levels of both topographic and planimetric data with accuracy levels commensurate with map scales of 1:250,000; 1:50,000; and 1:25,000. These requirements call for a considerable amount of detailed information, such as soil type, type of building material, and surface geology.

Special Map Products. This series of graphics cover a multitude of unique mapping requirements that include environmental inventories, escape and evasion graphics, and cross-country mobility maps. These graphics are produced at scales that are commensurate with the amount and type of details to be portrayed.

Hydrographic Charts. The hydrographic charts are also produced at a variety of scales and are primarily limited to near and offshore bathymetry, including aids to navigation. They are also required to show terrain features that can be used as an aid to navigation.

Operational Navigation Charts. These small-scale (1:1,000,000) charts are designed as a navigational aid to both the civilian and military aviator. The terrain and cultural features portrayed are usually limited to those major elements that provide recognizable points for air navigation.

LANDSAT Systems. The Earth Resources Technology Satellite (ERTS) Program, designated by the National Aeronautics and Space Administration (NASA) as a research and development program, was designed to demonstrate that remote sensing from space is a feasible and practical approach to efficient management of earth resources. The first satellite in this program, LANDSAT 1, was launched on 23 July 1972. The second satellite, similar in design and construction, was also placed in near polar orbit on 22 January 1975 and was named LANDSAT 2.

Two additional satellites are planned by NASA for the future. The first, LANDSAT 3, is scheduled for launch in September 1977 and will have an orbit similar to that of the two previous systems. The second, LANDSAT 4, is now in the design stage and is scheduled for launch after 1980. LANDSAT 4 will have a considerable number of payload differences from its predecessors. In addition, NASA is planning to have LANDSAT 4 be the first operational satellite and imaging system placed in orbit.

LANDSAT 1 and 2. In general, these two systems are identical in design and contain similar sensor subsystems.* For ease of description, these systems can be divided into five major categories:

1. Control.
2. Orbital platform.
3. Sensors and data transmission.
4. Sensor performance.
5. Sensor products.

Control. The Operations Control Center (OCC) located at the Goddard Space Flight Center (GSFC), Greenbelt, Md. provides direction and control of the orbital platform and sensor operations. The OCC is in operation 24 hours, and its activities are centered on the time table set by the velocity of the orbital platform and the ground receiver coverage capability. The receiving stations in Alaska, California, and GSFC provide contact with the platform during 12 to 13 of the 14 daily orbits. The platform circles the earth every 103 minutes at an altitude of approximately 925 km (494 nautical miles) in an approximate sun-synchronous orbit. It completes 14 orbits per day and requires 18 days to provide complete coverage of the earth. The ground track of each orbit is modified by the OCC in order that identical coverage of the ground area can be obtained every 18 days at a similar sun angle. Successive ground tracks are spaced 2,760 kilometers apart at the equator and are arranged to provide 14 percent sidelap. Because the ground tracks converge at the poles, the amount of sidelap increases to 85 percent at 80° north latitude, thus providing imagery that is suitable for stereo viewing. Successive image centers can be maintained to within 37 kilometers (20 nautical miles).

Sensor Systems. There are three remote sensor subsystems aboard LANDSAT 1 and 2 that weigh 240 kilograms and comprise approximately 30 percent of the total weight of the satellite. These subsystems include a Return Beam Vidicon (RBV) camera, a data collection system (DCS), and a multispectral scanner (MSS) (figure 1).

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*The reader is encouraged to consult the ERTS Data Users Handbook, published by NASA for a more complete description of these systems.

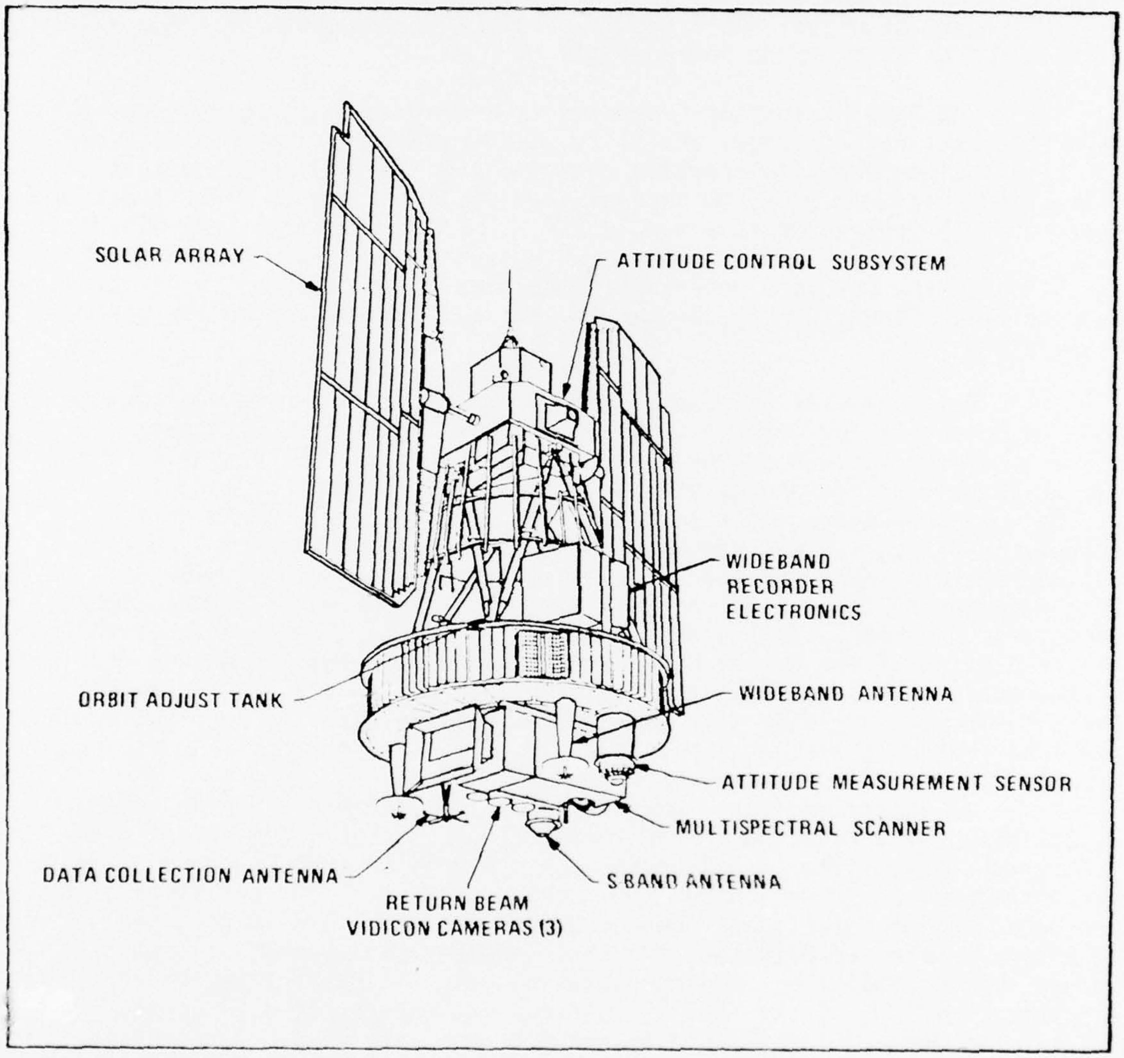

Figure 1. Schematic of LANDSAT I and II

NOTE: Figure obtained from the ERTS Data Users Handbook published by NASA.

The RBV camera consists of three cameras and lens systems operating in the following portions of the electromagnetic spectrum: Channel 1, .475 to .575 (green); Channel 2, .580 to .680 (red); Channel 3, .690 to .830 (infrared). The three cameras are aligned within the platform to view the same nominal 185 kilometers (100 nautical miles) square ground scene. In operation, these cameras have caused an excessive drain on the system's power supplies. As a result, very limited amounts of imagery are available from this system for analysis.

The Data Collection Subsystem is a nonimaging component consisting of a receiver, data storage capability, and transmitter that was designed to relay environmental information received from the ground-based Data Collection Platforms (DCP) to various user agencies. Up to eight individual sensors may be connected to a single DCP. The DCP transmits the collected data to the satellite, which in turn relays the data to the ground receiving site through the on-board receiver/transmitter. The data are received at the Goddard Space Flight Center, Greenbelt, Md. and distributed to the various agencies.

Multispectral Scanner. The MSS employs a single optical system and six detectors for each of the four channels to collect reflected energy from the surface of the earth (figure 2). The four channels simultaneously record energy of the following wavelengths: Channel 4, 0.5 to 0.6 micrometers (green); Channel 5, 0.6 to 0.7 micrometers (red); Channel 6, 0.7 to 0.8 micrometers (near infrared); and Channel 7, 0.8 to 1.1 micrometers (near infrared).* The instantaneous field of view of each detector subtends a ground area, essentially square in format, about 79 meters on a side. This design feature is important because it establishes the resolution of the entire MSS system. As an example, the energy received from a small lake located in the center of one of these 79- by 79-meter areas would be integrated with the energy received from the terrain surrounding the lake, making detection impossible.

In operation, the energy received from the surface of the earth is collected by a rotating mirror that reflects it through a set of fiber optics and glass filters, unique to each channel, to the detectors. The six detectors per channel change the light energy to electrical signals that are equal to one rotation of the mirror and one scan line. The signals received from the 24 detectors are then sampled, digitized, and formatted into a pulsed amplitude, modulated, serial, digital data stream by an electronic system. Cross- and along-track motion are produced by the rotating mirror and the forward movement of the satellite, respectively. The sampled data are then either transmitted directly to the analog-to-digital converter for encoding or, for channels 4 through 6, are directed to a logarithmic signal compression amplifier and then to the encoder. At this point, the data is either stored in the on-board recording facility or transmitted to the Ground Data Handling Facility at a rate of 15 megabits per second.

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*This numbering system was originated by NASA and is used in this report to be consistent with technical literature.

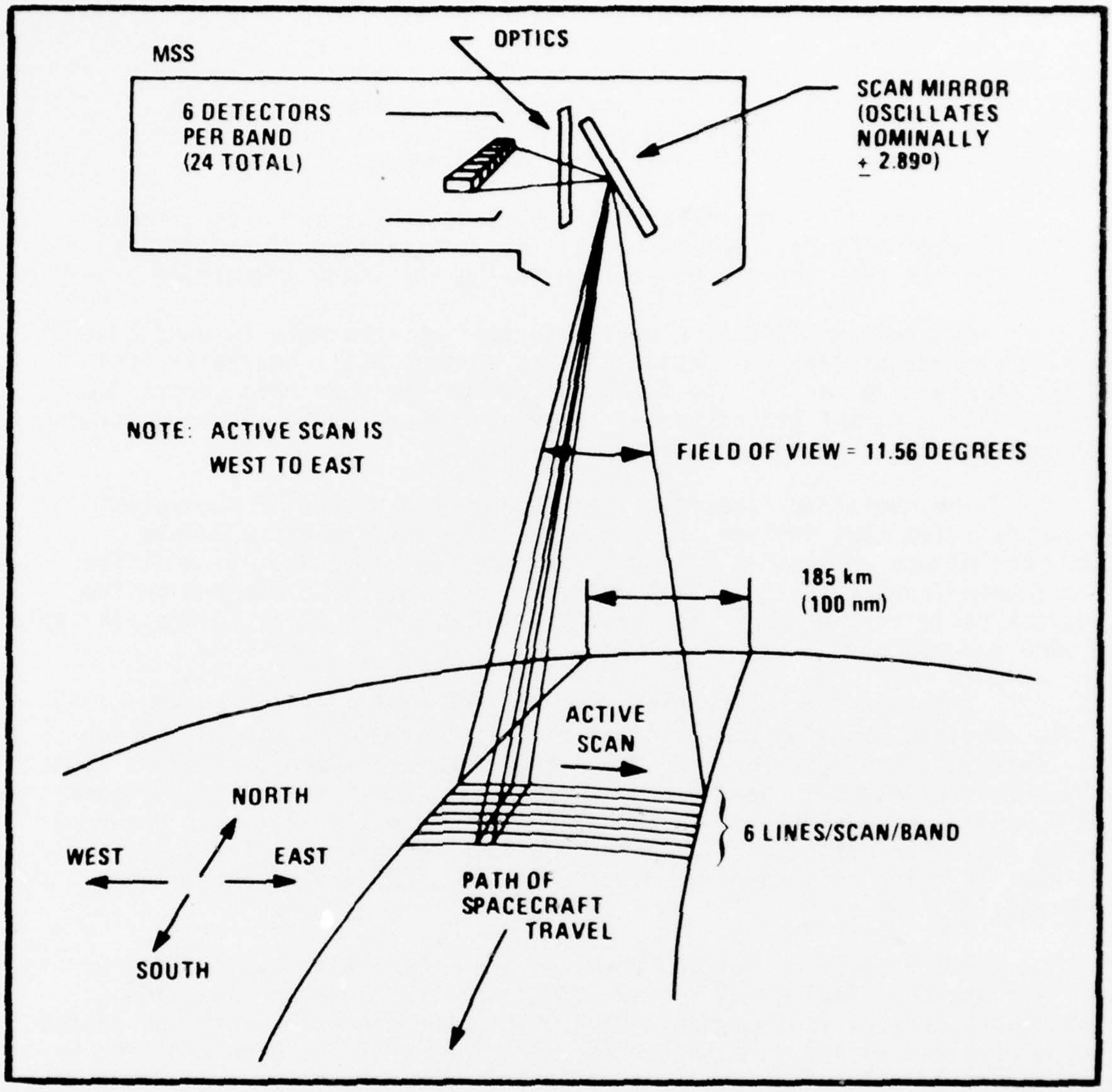

Figure 2. Schematic of Multispectral Scanner Subsystem

NOTE: Figure obtained from the ERTS Data Users Handbook published by NASA.

Sensor Performance. There are a number of design characteristics of the MSS subsystem that affect the quality of the imagery produced by this sensor. Those characteristics that are known and can be measured include amplitude resolution, spatial resolution, channel-to-channel registration, geometric fidelity, and relative radiometric accuracy. The first two of these, amplitude and spatial resolution, are inherent to the system and can not be modified from the ground.

Fortunately, the three most important characteristics (channel-to-channel registration, geometric fidelity, and radiometric accuracy) can be modified from the ground station during the image processing procedure.

Accurate registration of the various MSS channels to each other is aided by the single lens design of this system, but a source of error exists in the alignment of the fiber optics and the scan rate across the ground swath. As was stated above, these sources of error can be determined and corrected with varying degrees of success.

The geometric fidelity is dependent on a number of subsystem characteristics that include, for example, scan nonlinearity, sample time, and minute changes in platform altitude and attitude. In addition, it has been found that the actual geometric accuracy also depends on the contrast ratio of the scene and the number of ground control points available in each scene.

A method for calibrating the relative radiometric accuracy of the MSS is provided by using the scanning mirrors' retrace interval. During this interval, the detectors are fed energy from an on-board standard light source that provides a check on the radiometric levels of the four channels and equalizes any difference in the signal strength that may have occurred in the six-fiber-optic paths associated with each channel. The actual radiometric value of a terrain feature, however, can not be determined from MSS information.

MSS Products. Imagery obtained from the MSS is available from NASA and the U.S. Geological Survey (USGS) on both magnetic tape and photography derived from magnetic tape. Both the magnetic tapes and photos can be obtained either in bulk form or in a form that has been modified by a number of additional corrections. The bulk products receive the radiometric and geometric corrections introduced during the video tape to film conversion process but not the additional corrections available from the precision processing subsystem.

The precision processed tapes and photographs receive the same corrections as the bulk products, plus additional corrections to improve the radiometric and geometric accuracy of this product. The radiometric corrections, although increasing the reliability of the scene contrast range, do not permit absolute spectral analysis of the imagery. The geometric corrections, however, improve the positional accuracy of the product from 1,075 to 235 meters (film product) and a channel-to-channel registration from 155 to 150 meters.

The types of MSS products available are summarized as follows:

Product Type	Black and White	Color	Digital
Bulk	70-mm negative	9.5- by 9.5-inch positive	Computer Compatible Tapes
	70-mm positive	9.5-inch paper print	
	9.5-inch positive		
	9.5-inch paper print		
Precision	9.5-inch negative	9.5- by 9.5-inch positive	Computer Compatible Tapes
	9.5-inch positive	9.5-inch paper print	
	9.5-inch paper print		

LANDSAT 3. The third satellite in the NASA program is scheduled for launch in September 1977. This experimental system will weigh approximately 960 kilograms, have an overall height of 3.04 meters, a diameter of 1.5 meters, and the solar paddles will extend a distance of 3.96 meters.

The system will contain modified versions of the Multispectral Scanner (MSS), the Return Beam Vidicon (RBV) camera, and the Data Collection System (DCS) carried on LANDSAT 1 and 2.

MSS. With the exception of the addition of a fifth channel, operating in the emitted or thermal infrared range (10.4 to 12.6 micrometers), this sensor system is identical to the MSS used on LANDSATS 1 and 2. It will scan crosstrack swaths 185 kilometers wide, simultaneously imaging six scan lines in each of the first four channels and two lines in the fifth channel. Channels 4, 5, 6, and 7 will operate in the reflected solar spectral region from 0.5 to 1.1 micrometers wavelength. The thermal infrared channel (channel 8) will use mercury-cadmium-telluride, longwave infrared detector that are cooled to approximately 100^{o} K (Kelvin). The ground resolution of the first four channels is identical to LANDSATS 1 and 2 (table 2), but the ground resolution of channel 8 is limited to a square 240 by 240 meters. The data collection, transmission, and reduction procedures of LANDSAT 3 will also be similar in design to the previous systems except that this system will have two additional video channels.

Table 2. Summary of LANDSAT System Specifications

LANDSAT SYSTEM	DATE OF LAUNCH	CHANNEL NUMBER	GROUND RESOLUTION CELL (meters)	SPECTRAL CHARACTERISTICS (micrometers)	COVERAGE CYCLE (days)	ALTITUDE (kilometers)	EQUATORIAL CROSSING (hours)
1	7/23/72	4	79 X 79	0.5 - 0.6	18	918	0930
(A)		5	79 X 79	0.6 - 0.7			
		6	79 X 79	0.7 - 0.8			
		7	79 X 79	0.8 - 1.1			
2	1/22/75	4	79 X 79	0.5 - 0.6	18	918	0930
(B)		5	79 X 79	0.6 - 0.7			
		6	79 X 79	0.7 - 0.8			
		7	79 X 79	0.8 - 1.1			
3	9/77	4	79 X 79	0.5 - 0.6	18	914	0930
(C)		5	79 X 79	0.6 - 0.7			
		6	79 X 79	0.7 - 0.8			
		7	79 X 79	0.8 - 1.1			
		8	238 X 238	10.4 - 12.6			
4 *	1980 -	1	30 X 30	0.45 - 0.5	8 (2 satellites)	705	0930
(D)*	1985	2	30 X 30	0.52 - 0.6			
		3	30 X 30	0.63 - 0.69			
		4	30 X 30	0.76 - 0.90			
		5	30 X 30	1.55 - 1.75			
		6	120 X 120	10.4 - 12.5	16 (1 satellite)		

* LANDSAT 4 (D) will also contain an MSS system similar to the one used in LANDSAT 3 (C).

The RBV camera subsystem has an improved ground resolution capability over the previous system by a factor of two. This increase in resolution was accomplished by doubling the focal length of the objective lenses; removing the spectral, optical filters; and decreasing the time of exposure. The two cameras composing this subsystem will provide two adjacent panchromatic scenes of the earth, 98 by 98 kilometers in area. The cameras are oriented such that two successive scene pairs will provide the same terrain coverage as one MSS frame. The four scenes needed to fill each MSS scene will be designated A, B, C, and D.

The Data Collection System (DCS) on LANDSAT 3 will be essentially the same as on LANDSATS 1 and 2. Possibly, the total system may be expanded for the DCS to be used in areas outside North America.

Probably the most significant change in the NASA LANDSAT program is scheduled to take place in conjunction with the launching of LANDSAT 3. This change concerns the procedure in which the information received from the sensor system is processed. The information received from the first and second satellites was in analog form and was processed into first an image and then to digital tapes and photographs. At the present time, NASA is developing an all-digital processing system that should be in operation in time to process LANDSAT 3 information.

One advantage of this digital processing system is that it can produce approximately 200 scenes per day as opposed to the present system's production of 20 scenes per day. In addition, the new system should decrease the user's waiting time for LANDSAT products. The system should also produce more precise data that will enable better scene-to-scene registration than has been possible in the past.

Although the data production system has not been finalized, a recent NASA publication states two alternatives that will be offered.*

Alternative 1:

1. Imagery data produced by the cubic convolution resampling algorithm in the Space Oblique Mercator (SOM) projection (LANDSAT imagery is presently being produced in the SOM projection.).

2. Digital data resampled using the cubic convolution technique and produced in the Space Oblique Mercator format.

3. Digital data resampled using other algorithms and in other projections or unresampled data may be available at some additional cost pending final definition of the EDC system.

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*NASA Applications Notice, AN-OA-76-B, Inputs Requested from Earth Resources Remote Sensing Data Users Regarding LANDSAT-C Mission Requirements and Data Needs, 1976.

Alternative 2:

1. Imagery data produced by the cubic convolution resampling algorithm in the SOM projection (same as Alternative 1).

2. Digital data available only in the cubic convolution resampled, Space Oblique Mercator format.

The same NASA publication provides a list of the products, photographs, Computer Compatible Tapes (CCTS) that will be available to the public. Although it is not finalized, this list does not mention the availability of the 70-millimeter film chips previously available from each of the four channels of each LANDSAT scene. In place of the black-and-white 70-millimeter chips, NASA will offer both film and paper products in a 241- by 241-millimeter (9.5- by 9.5-inch) format.

The total impact of the changes in both the data processing procedures and the available products has not been fully realized by the consumers. Some concern, however, has been expressed. The increased format size and the emphasis placed on the use of digital data by NASA will have a considerable effect on not only the amount of information available from the imagery but also the precision in which the data is formatted.

The increased image format size will create a hardship on those consumers that have invested funds in 70-millimeter additive color viewers that can only be utilized by cutting the 9.5- by 9.5-inch imagery into 70-millimeter chips. Also, considerable concern is expressed by those consumers that do not have either in-house computer capability or the funds necessary to acquire the computer time associated with the analysis of CCTS.

LANDSAT 4. The LANDSAT "follow-on" system scheduled to be placed in operation after 1980 is the first satellite in the NASA program to be considered operational rather than experimental in design. At this date, neither the operational aspects of the spacecraft nor the design of the sensor subsystems are considered final.

To meet stated user requirements for an operational system and to decrease the image acquisition time cycle, a number of major changes have been proposed for the LANDSAT 4 system. The changes include using three spacecraft, using a lower orbital-altitude-improved remote sensor system, adding a blue band (.45 to .52 micrometers), reducing the data processing/reproduction cycle time, and deleting the Data Collection System (DCS).

Two of the spacecraft employed in this system will carry the remote sensor subsystem, the data relay equipment, and the hardware necessary for control and stabilization of the platform. These platforms will be orbited

at an altitude of 705 kilometers* and will be oriented to provide imagery of the terrain on a 9-day cycle. The third spacecraft will serve as a relay station to transmit data from each satellite to the ground station. There have been two equatorial crossing times discussed for the descending mode of the orbits: 0930 and 1100 hours. At this writing, the final equatorial crossing time has not been decided.

Two remote sensor subsystems are proposed for each of the remote sensor platforms.** One will have the same design and ground resolution characteristics as the MSS used on LANDSAT 3. The second, with increased ground resolution capabilities, is called a Thematic Mapper.

Three contractors are presently competing to produce the production model of this subsystem. Two models are line scanners, somewhat similar in design to the present MSS (LANDSAT 3), and although the third model also employs a single lens system, it has a conical scan similar to the S192 scanner used on SKYLAB. An additional feature of this design is a dispersive radiometer system that in theory, at least, should permit better radiometric control of the imagery. Regardless of the final scanner design selected, the NASA specifications require this subsystem to have six channels, three in the visible, two in the near or reflected infrared, and one in the thermal infrared portion of the spectrum (table 2). The visible and near infrared channels will have a ground pixel, square in format, equal to 30 meters on a side, and the thermal infrared channel will be limted to 120 by 120 meters.

The quantizing levels of LANDSAT 4 have also been increased from 64 levels (MSS, 6 bits) to 256 levels (8 bits). In a photograph this increase in the number of gray levels, in theory, would increase the information content of the photograph fourfold.

The data transmission and reduction system for LANDSAT 4 is still under consideration, but based on available information, it will be similar in design to the LANDSAT 3 system. The increase in the amount of spatial, spectral, and radiometric information will necessitate a major increase in the processing capability and, therefore, the cost of this program.

The proposed product list for this system will follow that proposed for LANDSAT 3 with major emphasis placed on using digital data (CCTS) rather than photography. By using digital data, NASA can reduce their photographic laboratory requirements and thereby reduce their system costs, can provide more information, and can transmit data to the user within a shorter time period.

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*This altitude was proposed to increase ground resolution and to enable servicing to be performed from the space shuttle craft.

** Based on personal communication with Mr. G. Schulman, Program Manager, LANDSAT D, NASA, this system will be limited to one satellite.

RESULTS

The analysis of LANDSAT 1 and 2 systems is presented in table 3,* which has been organized into three major divisions.

1. Cartographic and Terrain Requirements. These requirements represent the range of specific terrain and environmental detail needed by DOD for operational and cartographic purposes.

2. Map and Chart Specifications. The requirements for each of the nine maps selected for this analysis are identified by map type and scale. Because of flexibility within the specifications, the Map Elements are identified by S if they are specified and P if they are not. However, those elements marked P may appear on a map or chart because of their importance as a landmark.

3. LANDSAT Systems. This section of the table has seven subsections, as follows:

Geographic Regions - Since the detectability of certain terrain features or patterns is often dependent on the type of topography and terrain in which they are located, those regions, when LANDSAT data is discerned to be effective, have been noted.

Channels Employed - The individual or combination of LANDSAT channels found to be the most useful in providing information on a particular Map Element are noted.

Seasonal or Repetitive Coverage - The use or requirement for temporal LANDSAT data or imagery to detect a certain Map Element is recorded by season: Spring, Summer, Fall, and Winter.

Data Type - The type of LANDSAT information required (imagery, digital) to detect each Map Element.

References - Those technical and scientific reports applicable to each Map Element are numbered in sequence and may be found in the Bibliography.

Systems Analysis Code - Four levels of the analysis code were developed for this study: 0 - Not detectable, the Map Element can not be discerned or located from either type of LANDSAT data; 1 - Detectable, Map Element can be detected but not identified from the type of LANDSAT data indicated; 2 - Identifiable, Map Element can be detected and recognized as a particular type of feature from the LANDSAT data indicated, e.g. road, canal, etc., however collateral information may be required to reach this analysis level; 3 - Classifiable, LANDSAT data, with the use of all available information, can provide the information required for the Map Element including

*The nonoperational LANDSAT systems, 3 and 4, could not be analyzed in depth because of a lack of information.

all required measurements, e.g. width, length, and areas. As an example, a highway could be detected on LANDSAT imagery but information such as designation, width, and weight limit would have to be obtained from other sources.

Table 3. Summary of Analysis of LANDSAT Systems 1 and 2

CARTOGRAPHIC AND TERRAIN REQUIREMENTS	MAP AND CHART SPECIFICATIONS[1]									LANDSAT SYSTEMS - 1, 2													
						HYDROGRAPHIC CHARTS				GEOGRAPHIC[2] REGIONS				CHANNELS[3] EMPLOYED					DATA[5] TYPE				
MAP ELEMENT	CITY MAPS	TOPOGRAPHIC 1:50,000	JOINT OPERATIONS GRAPHIC 1:250,000	DIGITAL RADAR LANDMASS SIMULATOR (DRLS)	SPECIAL MAP PRODUCTS	1:50,000	1:100,000	1:250,000	OPERATIONAL NAVIGATION CHART 1:1,000,000	ARCTIC	TEMPERATE	DESERT	TROPIC	4	5	6	7	SEASONAL AND/OR REPETITIVE COVERAGE[4]	IMAGERY	CCTS	REFERENCE[6]	SYSTEMS ANALYSIS CODE[7]	NOTE #8
A. LINES OF COMMUNICATION.																							
1. Hard Surface Roads	S	S	S	S	S	S	S	S	S	X	X	X	X		X	X	X	SP,F,W	X	X	1,2,3,4	2	LS-1 C-1
Divided highways median strip	S	S	S	S	S	S	S	S	S	X	X	X	X		X	X	X	SP,F,W	X	X	1,2,3,4	2	
Divided highways	S	S	S	S	S	S	S	S	S	X	X	X	X		X	X	X	SP,F,W	X	X	1,2,4	2	
Interchanges	S	S	S	S	S	S	S	S	S	X	X	X	X		X	X	X	S,F,SP	X	X	1,3,4	2	
Two lane roads	S	S	S	S	S	S	S	S	S	X	X	X	X		X	X	X	S,F,SP	X	X	1,3,5	2	
One lane roads	S	S	S	S	S	P	P	P	P	X	X	X	X		X	X	X	S,F,SP	X	X	1,3,5	2	

[1]S - Specified in Map Requirement.
P - Not Specified, But May Appear on Map.

[2]"X" Denotes Geographic Regions Where LANDSAT Imagery has been Applied.

[3]"X" Denotes LANDSAT Channels Employed. (_) Indicates Preferred Channel.

[4]SP - Spring
S - Summer
W - Winter
F - Fall

[5]"X" Denotes Type of Data Used.

[6]See List of References, Page __.

[7]0 - Not Detectable
1 - Detectable
2 - Identifiable
3 - Classifiable

[8]C - Cartographic Note.
LS- LANDSAT Systems Note.
Appendixes A and B, Respectively.

CARTOGRAPHIC AND TERRAIN REQUIREMENTS	MAP AND CHART SPECIFICATIONS[1]									LANDSAT SYSTEMS - 1, 2													
						HYDROGRAPHIC CHARTS				GEOGRAPHIC[2] REGIONS				CHANNELS[3] EMPLOYED					DATA[5] TYPE				
MAP ELEMENT	CITY MAPS	TOPOGRAPHIC 1:50,000	JOINT OPERATIONS GRAPHIC 1:250,000	DIGITAL RADAR LANDMASS SIMULATOR (DRLS)	SPECIAL MAP PRODUCTS	1:50,000	1:100,000	1:250,000	OPERATIONAL NAVIGATION CHART 1:1,000,000	ARCTIC	TEMPERATE	DESERT	TROPIC	4	5	6	7	SEASONAL AND/OR REPETITIVE COVERAGE[4]	IMAGERY	CCTS	REFERENCE[6]	SYSTEMS ANALYSIS[7] CODE	NOTE #8
2. Loose Surface Roads (All Weather)	S	S	S	S	S	P	P	P	P	X	X	X	X		X	X	X	S,F,SP	X	X	1,3,6,7 8	2	
3. Loose Surface Roads (Dry Weather)	S	S	S	S	S	P	P	P	P	X	X	X	X		X	X	X	S,F,SP	X	X	1,6,7,8	2	
4. Road Specifica-tions	S			S	S																	0	
Weight class	P			S	S																	0	
Surface material	P			S	S																	0	
Width	S	S	S	S	S																	0	
5. Track	S	S	S	S	S				P	X	X	X			X	X	X	SP,F,W	X	X	1,5	1	
6. Trail	S	S	S		S				P	X	X	X			X	X	X	SP,F,W	X	X	6,7	1	
7. Footpath	S	S	S		S				P													0	
8. Through Routes	S	P	P	S	S	S	P	P	S	X	X	X	X		X	X	X	SP,F,W	X	X	6,7,8	2	
9. Streets	S	S	P	S	S					X	X	X	X		X	X	X	SP,F,W	X	X	8	1	LS-2 C-2
Width	S		P	S	S																	0	
Surface material	S			S	S																	0	
10. Deadend Streets	S	S	P		S																	0	
11. Traffic Circles	S	S	S	S	S																	0	
12. Parking Lots	S			S	S					X	X	X	X		X	X	X	S,F,W		X	9	2	LS-2

CARTOGRAPHIC AND TERRAIN REQUIREMENTS	MAP AND CHART SPECIFICATIONS[1]									LANDSAT SYSTEMS - 1, 2													
						HYDROGRAPHIC CHARTS				GEOGRAPHIC[2] REGIONS				CHANNELS[3] EMPLOYED					DATA[5] TYPE				
MAP ELEMENT	CITY MAPS	TOPOGRAPHIC 1:50,000	JOINT OPERATIONS GRAPHIC 1:250,000	DIGITAL RADAR LANDMASS SIMULATOR (DRLS)	SPECIAL MAP PRODUCTS	1:50,000	1:100,000	1:250,000	OPERATIONAL NAVIGATION CHART 1:1,000,000	ARCTIC	TEMPERATE	DESERT	TROPIC	4	5	6	7	SEASONAL AND/OR REPETITIVE COVERAGE[4]	IMAGERY	CCTS	REFERENCE[6]	SYSTEMS ANALYSIS CODE[7]	NOTE #[8]
12. Parking Lots (cont.)																							
Area				S	S																	0	
Surface material	S			S	S																	0	
13. Streetcar Lines	S		P	S	S				P													0	
Gauge					S																	0	
14. Bridge Location	S	S	S	S	S	P	P	P	S	X	X	X	X		X			SP,F,W	X	X		1	LS-3
15. Bridge Specifications	S	P	P	S	S				P													0	
Type (RR,road)	S	P		S	S	P	P	P	S	X	X	X	X		X			SP,F,W	X	X	8	2	LS-4
Width	S		P	S	S																	0	
Length	S			S	S																	0	
Weight class				S	S																	0	
Construction material	P			S	S				S													0	
Overhead clearance	S		P																			0	
16. Causeway Location	S	S	S	S	S	S	S	S	S	X	X	X	X		X	X	X	SP,F,W	X	X	None	2	LS-4

CARTOGRAPHIC AND TERRAIN REQUIREMENTS	MAP AND CHART SPECIFICATIONS[1]									LANDSAT SYSTEMS - 1, 2													
						HYDROGRAPHIC CHARTS				GEOGRAPHIC[2] REGIONS				CHANNELS[3] EMPLOYED					DATA[5] TYPE				
MAP ELEMENT	CITY MAPS	TOPOGRAPHIC 1:50,000	JOINT OPERATIONS GRAPHIC 1:250,000	DIGITAL RADAR LANDMASS SIMULATOR (DRLS)	SPECIAL MAP PRODUCTS	1:50,000	1:100,000	1:250,000	OPERATIONAL NAVIGATION CHART 1:1,000,000	ARCTIC	TEMPERATE	DESERT	TROPIC	4	5	6	7	SEASONAL AND/OR REPETITIVE COVERAGE[4]	IMAGERY	CCTS	REFERENCE[6]	SYSTEMS ANALYSIS CODE[7]	NOTE #[8]
17. Causeway Specifications	S			S	S																	0	
Type (RR,road)	S			S	S					X	X	X	X		X	X	X	S,F,W	X	X	8	2	LS-4
Elevation				S	S																	0	
Width	P			S	S																	0	
Length	S			S	S																	0	
Construction material				S	S																	0	
Surface material	P			S	S																	0	
18. L.O.C. Cuts and Fills	S	S		S	S					X	X	X	X	X	X			S,F,SP	X	X	None	1	LS-5 C-3
Type	S			S	S																	0	
Length	S			S	S																	0	
Height				S	S																	0	
19. Tunnels	S	S	S	S	S	S	S	S	S	X	X	X	X	X	X			SP,S,W,F	X	X	None	1	LS-4
Type (RR,road)	S				S																	0	
Construction material					S																	0	
Length	S	S	P	P	S																	0	
Width		S	P	P	S																	0	

CARTOGRAPHIC AND TERRAIN REQUIREMENTS	MAP AND CHART SPECIFICATIONS[1]									LANDSAT SYSTEMS - 1, 2														
						HYDROGRAPHIC CHARTS				GEOGRAPHIC[2] REGIONS				CHANNELS[3] EMPLOYED					DATA[5] TYPE					
MAP ELEMENT	CITY MAPS	TOPOGRAPHIC 1:50,000	JOINT OPERATIONS GRAPHIC 1:250,000	DIGITAL RADAR LANDMASS SIMULATOR (DRLS)	SPECIAL MAP PRODUCTS	1:50,000	1:100,000	1:250,000	OPERATIONAL NAVIGATION CHART 1:1,000,000	ARCTIC	TEMPERATE	DESERT	TROPIC	4	5	6	7	SEASONAL AND/OR REPETITIVE COVERAGE[4]	IMAGERY	CCTS	REFERENCE[6]	SYSTEMS ANALYSIS[7] CODE	NOTE #[8]
19. Tunnels (cont.)																							
Overhead clearance	S	S	P	P	S																	0	
20. Over-, Under-pass	S	S	S	S	S				S													0	
Type	S	S	S	S	S																	0	
Construction material				S	S																	0	
Width	P				S																	0	
Length	S	S	P		S																	0	
Height	P				S																	0	
21. Ferry Location	S	S	S	S	S	P	P	P	S	X	X	X	X		X		X	SP,S	X	X	None	1	LS-4
22. Fords	S	S	S	S	S				S	X	X	X	X		X		X	SP,S	X	X	None	1	LS-4
Width					S																	0	
Length					S																	0	
Bottom material					S																	0	
Current					S																	0	
23. RR Gauge	S	S	S	S	S					X	X	X	X		X				X	X	None	1	LS-5
No. of tracks	S	S	S	S	S	S	S	S	S	X	X	X	X		X				X	X	None	1	LS-6
RR power (type)	S	S	P	S	S				S													0	

CARTOGRAPHIC AND TERRAIN REQUIREMENTS	MAP AND CHART SPECIFICATIONS[1]									LANDSAT SYSTEMS - 1, 2													
						HYDROGRAPHIC CHARTS				GEOGRAPHIC[2] REGIONS				CHANNELS[3] EMPLOYED					DATA[5] TYPE				
MAP ELEMENT	CITY MAPS	TOPOGRAPHIC 1:50,000	JOINT OPERATIONS GRAPHIC 1:250,000	DIGITAL RADAR LANDMASS SIMULATOR (DRLS)	SPECIAL MAP PRODUCTS	1:50,000	1:100,000	1:250,000	OPERATIONAL NAVIGATION CHART 1:1,000,000	ARCTIC	TEMPERATE	DESERT	TROPIC	4	5	6	7	SEASONAL AND/OR REPETITIVE COVERAGE[4]	IMAGERY	CCTS	REFERENCE[6]	SYSTEMS ANALYSIS[7] CODE	NOTE #[8]
23. RR Gauge (cont.)																							
Sidings	S	S	S	S	S				S													0	
Spur	S	S	P	S	S				S													0	
Elevation				S	S																	0	
RR yards	S	S	S	S	S				S	X	X	X	X		X			W,SP,F	X	X	None	2	C-4
Width	S		P	S	S				P													0	
Length	S		P	S	S				P													0	
24. RR Structures	S	S	S	S	S				S													0	
Construction type	S			S	S																	0	
Length	S			S	S																	0	
Width	S			S	S																	0	
Overhead clearance	S				S																	0	
Construction material	S			S	S																	0	
Height	S			S	S																	0	
B. CULTURE.																							
1. Land Use	S				S					X	X	X	X		X		X	SP,S,F	X	X	10,11,12 13,14,15	3	LS-6

CARTOGRAPHIC AND TERRAIN REQUIREMENTS	MAP AND CHART SPECIFICATIONS[1]									LANDSAT SYSTEMS - 1, 2													
						HYDROGRAPHIC CHARTS				GEOGRAPHIC[2] REGIONS				CHANNELS[3] EMPLOYED						DATA[5] TYPE			
MAP ELEMENT	CITY MAPS	TOPOGRAPHIC 1:50,000	JOINT OPERATIONS GRAPHIC 1:250,000	DIGITAL RADAR LANDMASS SIMULATOR (DRLS)	SPECIAL MAP PRODUCTS	1:50,000	1:100,000	1:250,000	OPERATIONAL NAVIGATION CHART 1:1,000,000	ARCTIC	TEMPERATE	DESERT	TROPIC	4	5	6	7	SEASONAL AND/OR REPETITIVE COVERAGE[4]	IMAGERY	CCTS	REFERENCE[6]	SYSTEMS ANALYSIS[7] CODE	NOTE #[8]
1. Land Use (cont.)																							
Cultivated Land	S	P	P	S	S																14, 15, 16	3	
Crop type					S					X	X	X	X		X		X	SP,S,F	X	X	11	2	LS-7
Farmsteads	S	P	S	S	S				P													0	
Farm type	S				S																	0	
Rice paddies	S	S	S	P	S						X		X		X		X		X	X	None	1	
2. Populated Areas	S	S	S	S	S				S	X	X	X	X		X	X	X	S,F,SP	X	X	15,16, 17	2	LS-8
Residential	S			S	S										X	X	X	S,F,SP	X	X	15,16, 17,19	2	
Government	S			S	S																	0	
Industrial	S			S	S					X	X	X	X		X	X	X	S,F,SP	X	X	12,15, 16,17	2	
Commercial	S			S	S					X	X	X	X		X	X	X	S,F,SP	X	X	12,15, 16,17, 18,19	2	
Tennis Courts	S			S	S																	0	
3. Buildings	S	S	P	S	S	P	P	P	P	X	X	X	X		X		X	SP,S,F W	X		None	1	LS-6
Height	S	P		S	S				P													0	
Width	S	P		P	S																	0	
Length	S	P		P	S																	0	

CARTOGRAPHIC AND TERRAIN REQUIREMENTS	MAP AND CHART SPECIFICATIONS[1]									LANDSAT SYSTEMS - 1, 2													
						HYDROGRAPHIC CHARTS				GEOGRAPHIC[2] REGIONS				CHANNELS[3] EMPLOYED					DATA[5] TYPE				
MAP ELEMENT	CITY MAPS	TOPOGRAPHIC 1:50,000	JOINT OPERATIONS GRAPHIC 1:250,000	DIGITAL RADAR LANDMASS SIMULATOR (DRLS)	SPECIAL MAP PRODUCTS	1:50,000	1:100,000	1:250,000	OPERATIONAL NAVIGATION CHART 1:1,000,000	ARCTIC	TEMPERATE	DESERT	TROPIC	4	5	6	7	SEASONAL AND/OR REPETITIVE COVERAGE[4]	IMAGERY	CCTS	REFERENCE[6]	SYSTEMS ANALYSIS CODE[7]	NOTE #[8]
3. Buildings (cont.)																							
Roof area	S	P		S	S																	0	
Construction material				S	S																	0	
Use	P	P	P	P	S																	0	
Trailer parks	S	P		S	S					X	X	X	X		X		X	SP,W,F	X	X	None	1	LS-9
4. Ruins	S	S	S	P	S	P	P	P	P													0	
5. Towers	S	S	S	S	S	S	S	S	S													0	
Type	S	P	P	S	S	S	S	S	S													0	
Height	S	P	P	S	S				S													0	
Construction material	S			S	S																	0	
6. Light Houses	S	S	S	S	S	S	S	S	S													0	
Type	S	S	P	S	S	S	S	S	S													0	
Height	S	P	P	S	S	S	S	S	S													0	
7. Electrical Sub-stations	S	S	P	S	S																	0	
Type	S			S	S																	0	
Dimensions	P			S	S																	0	

CARTOGRAPHIC AND TERRAIN REQUIREMENTS	MAP AND CHART SPECIFICATIONS[1]									LANDSAT SYSTEMS - 1, 2														
						HYDROGRAPHIC CHARTS				GEOGRAPHIC[2] REGIONS				CHANNELS[3] EMPLOYED					DATA[5] TYPE					
MAP ELEMENT	CITY MAPS	TOPOGRAPHIC 1:50,000	JOINT OPERATIONS GRAPHIC 1:250,000	DIGITAL RADAR LANDMASS SIMULATOR (DRLS)	SPECIAL MAP PRODUCTS	1:50,000	1:100,000	1:250,000	OPERATIONAL NAVIGATION CHART 1:1,000,000	ARCTIC	TEMPERATE	DESERT	TROPIC	4	5	6	7	SEASONAL AND/OR REPETITIVE COVERAGE[4]	IMAGERY	CCTS	REFERENCE[6]	SYSTEMS ANALYSIS CODE[7]	NOTE #[8]
8. Power Plants	S	S	P	S	S	P	P	P	P	X	X	X	X		X			W,SP,S,F	X	X	None	1	LS-9
Type (fuel)	P				S																	0	
Output	P				S																	0	
9. Greenhouses	S	P	P	P	S																	0	
10. Pipelines	S	S	S	S	S	S	S	S	P													0	
Type	S				S	S	S	S														0	
Size	P				S																	0	
Capacity	P				S																	0	
11. Powerlines	S	S	S	S	S	P	P	P	P	X	X	X	X	X	X	X	X	S,F	X	X	1,7,26	1	LS-10
Capacity	P				S																	0	
Tower height	P			S	S				S													0	
Tower location	S	S	S	S	S	P	P	P	S													0	
12. Wells	S	S	P		S				P													0	
Type	S				S																	0	
Depth	P				S																	0	
Capacity	P				S																	0	
13. Storage Tanks	S	S	S	S	S	P	P	P	S	X	X	X	X		X	X	X	SP,S,F,W	X	X	None	1	LS-11
Type	S				S																	0	

CARTOGRAPHIC AND TERRAIN REQUIREMENTS	MAP AND CHART SPECIFICATIONS[1]									LANDSAT SYSTEMS - 1, 2													
						HYDROGRAPHIC CHARTS				GEOGRAPHIC[2] REGIONS				CHANNELS[3] EMPLOYED					DATA[5] TYPE				
MAP ELEMENT	CITY MAPS	TOPOGRAPHIC 1:50,000	JOINT OPERATIONS GRAPHIC 1:250,000	DIGITAL RADAR LANDMASS SIMULATOR (DRLS)	SPECIAL MAP PRODUCTS	1:50,000	1:100,000	1:250,000	OPERATIONAL NAVIGATION CHART 1:1,000,000	ARCTIC	TEMPERATE	DESERT	TROPIC	4	5	6	7	SEASONAL AND/OR REPETITIVE COVERAGE[4]	IMAGERY	CCTS	REFERENCE[6]	SYSTEMS ANALYSIS CODE[7]	NOTE #[8]
13. Storage Tanks (cont.)																							
Capacity	P				S																	0	
Height	P				S																	0	
Elevation	P				S				P													0	
14. Telephone Lines	P				P				P													0	
Terminals	S				S																	0	
15. Fence Lines	S	P	P	S	S				P													0	
Type material	S	P	P	S	S				P													0	
Height				P	S																	0	
16. Stadiums	S	S	S	S	S	P	P	P	P	X	X	X	X		X	X	X	SP,S,F,W	X	X	None	1	LS-6
Height				S	S																	0	
Material				S	S																	0	
Dimensions			P	S	S																	0	
17. Race Tracks	S	S	S	S	S	P	P	P	P	X	X	X	X		X	X	X	SP,S,F	X	X	None	1	LS-6
Height	P			S	S																	0	
Size	P	P	P	S	S																	0	
Material				S	S																	0	

CARTOGRAPHIC AND TERRAIN REQUIREMENTS	MAP AND CHART SPECIFICATIONS[1]									LANDSAT SYSTEMS - 1, 2													
								HYDROGRAPHIC CHARTS		GEOGRAPHIC[2] REGIONS				CHANNELS[3] EMPLOYED					DATA[5] TYPE				
MAP ELEMENT	CITY MAPS	TOPOGRAPHIC 1:50,000	JOINT OPERATIONS GRAPHIC 1:250,000	DIGITAL RADAR LANDMASS SIMULATOR (DRLS)	SPECIAL MAP PRODUCTS	1:50,000	1:100,000	1:250,000	OPERATIONAL NAVIGATION CHART 1:1,000,000	ARCTIC	TEMPERATE	DESERT	TROPIC	4	5	6	7	SEASONAL AND/OR REPETITIVE COVERAGE[4]	IMAGERY	CCTS	REFERENCE[6]	SYSTEMS ANALYSIS CODE[7]	NOTE #[8]
18. Cemeteries	S	S	S		S																	0	
19. Churches	S	S	S		S	P	P	P	S													0	
20. Schools	S	S			S	P	P	P														0	
21. Mines	S	S	S	P	S	S	S	P	P	X	X	X	X		X	X	X	SP,S,F	X	X	20,21,22 23,25	1	LS-12
Type	P	P	S	S	S					X	X	X	X		X	X	X	SP,S,F,W	X	X	None	1	
Size				S	S																	0	
22. Quarries	S	S	S	S	S	S	S	P	S	X	X	X	X		X	X	X	SP,S,F,W	X	X	20,21,22, 22A	1	LS-12
Type	P	P		S	S					X	X	X	X	X	X	X	X	SP,S,F,W	X	X	None	1	
Dimensions			P	S	S	P	P															0	
23. Airfields	S	S	S	S	S	S	S	P	S	X	X	X	X		X		X	SP,S,F,W	X	X	1,17	1	
Type	S	S	S	S	S	P	P	P	S													0	
Length of run-ways	S	S	S	S	S				S													0	
Width of run-ways	S	P	S	S	S				S													0	
Surface material	S	P	S	S	S				P													0	
Altitude	S	S	S	S	S				S													0	

CARTOGRAPHIC AND TERRAIN REQUIREMENTS	MAP AND CHART SPECIFICATIONS[1]					HYDROGRAPHIC CHARTS				LANDSAT SYSTEMS - 1, 2 GEOGRAPHIC REGIONS[2]				CHANNELS[3] EMPLOYED					DATA[5] TYPE				
MAP ELEMENT	CITY MAPS	TOPOGRAPHIC 1:50,000	JOINT OPERATIONS GRAPHIC 1:250,000	DIGITAL RADAR LANDMASS SIMULATOR (DRLMS)	SPECIAL MAP PRODUCTS	1:50,000	1:100,000	1:250,000	OPERATIONAL NAVIGATION CHART 1:1,000,000	ARCTIC	TEMPERATE	DESERT	TROPIC	4	5	6	7	SEASONAL AND/OR REPETITIVE COVERAGE[4]	IMAGERY	CCTS	REFERENCE[6]	SYSTEMS ANALYSIS[7] CODE	NOTE #[8]
23. Airfields (cont)																							
Direction of runways		S	S	S	S	S	S	S	S													0	
24. Outdoor Theaters	S	S	S	S	S	P	P	P	S	X	X	X	X		X			SP,S,F,W	X	X	None	1	
25. Forts	S	S	S	S	S	S	S	P	S													0	
D. HYDROLOGY.																							
1. Streams, Rivers	S	S	S	S	S	S	S	S	S	X	X	X	X		X		X	SP,F,W	X	X	1,14,15, 24,25,27, 28	2	C-5 C-6 LS-13
Width	P	P	S	S	S	S	S	S	S													0	
Bank slope					S																	0	
Bank material					S					X	X	X			X	X	X	W,SP	X	X	None	2	LS-14
Bank height					S																	0	
Depth					S																	0	
Sand bars	S	S	S	S	S	S	S	S	S	X	X	X	X		X	X	X	W,SP,S,F	X	X	None	1	
2. Rapids	S	S	S	S	S				P						X	X	X	W,SP,S,F	X	X	None	1	
3. Falls	S	S	S	S	S				P						X	X	X	W,SP,S,F	X	X	None	1	
4. Obstructions			S		S																	0	
5. Flood Plains	S	S	S	P	S				P	X	X	X	X		X	X	X	SP,S,F	X	X	29	2	LS-15

CARTOGRAPHIC AND TERRAIN REQUIREMENTS	MAP AND CHART SPECIFICATIONS[1]									LANDSAT SYSTEMS - 1, 2													
						HYDROGRAPHIC CHARTS				GEOGRAPHIC[2] REGIONS				CHANNELS[3] EMPLOYED					DATA[5] TYPE				
MAP ELEMENT	CITY MAPS	TOPOGRAPHIC 1:50,000	JOINT OPERATIONS GRAPHIC 1:250,000	DIGITAL RADAR LANDMASS SIMULATOR (DRLS)	SPECIAL MAP PRODUCTS	1:50,000	1:100,000	1:250,000	OPERATIONAL NAVIGATION CHART 1:1,000,000	ARCTIC	TEMPERATE	DESERT	TROPIC	4	5	6	7	SEASONAL AND/OR REPETITIVE COVERAGE[4]	IMAGERY	CCTS	REFERENCE[6]	SYSTEMS ANALYSIS CODE[7]	NOTE #8
5. Flood Plains (cont.)																							
Elevation	S	P	P		S																	0	
Area	S	S	S	P	S					X	X	X	X		X	X	X	SP,S,F,W	X	X	None	1	
6. Flood Area					S					X	X	X	X		X		X				30-34	2	
7. Levees	S	S	S	S	S					X	X	X	X		X		X		X	X	None	2	LS-15
Dimensions	S	S	S	S	S																	0	
Construction material				S	S																	0	
Elevation				S	S																	0	
8. Canals	S	S	S	S	S	P	P	P	S	X	X	X	X		X		X	SP,S,F	X	X	37	2	
Width	S	P	P	S	S				P													0	
Construction material				S	S																	0	
Locks	S	S	S	S	S	P	P	P	S													0	
Length				S	S	P	P	P														0	
Width				S	S																	0	
9. Irrigation Channels	S	S	S	P	S				P		X	X			X		X	SP,S,W	X		None	1	
Width					S																	0	

CARTOGRAPHIC AND TERRAIN REQUIREMENTS	MAP AND CHART SPECIFICATIONS[1]								
MAP ELEMENT	CITY MAPS	TOPOGRAPHIC 1:50,000	JOINT OPERATIONS GRAPHIC 1:250,000	DIGITAL RADAR LANDMASS SIMULATOR (DRLS)	SPECIAL MAP PRODUCTS	HYDROGRAPHIC CHARTS 1:50,000	HYDROGRAPHIC CHARTS 1:100,000	HYDROGRAPHIC CHARTS 1:250,000	OPERATIONAL NAVIGATION CHART 1:1,000,000
9. Irrigation Channels (cont.)									
Type (material)					S				
Source					S				
10. Water Bodies	S	S	S	S	S				S
Water quality	P				S				
Elevations	S	S	S	S	S				
Dimensions				S	S				S
Depth					S				
11. Dams	S	S	S	S	S	P	P	P	S
Construction material	P	P	S	S					
Height				S	S	P	P	P	S
Length				S	S				
Type				S	S				
12. Swamps	S	S	S	S	S	S	S	S	S
Area				S	S	S	S	S	S
Direction of current				S					

CARTOGRAPHIC AND TERRAIN REQUIREMENTS	LANDSAT SYSTEMS - 1, 2													
MAP ELEMENT	GEOGRAPHIC[2] REGIONS: ARCTIC	TEMPERATE	DESERT	TROPIC	CHANNELS[3] EMPLOYED: 4	5	6	7	SEASONAL AND/OR REPETITIVE COVERAGE[4]	DATA[5] TYPE: IMAGERY	CCTS	REFERENCE[6]	SYSTEMS ANALYSIS[7] CODE	NOTE #[8]
9. Irrigation Channels (cont.)														
Type (material)													0	
Source													0	
10. Water Bodies	X	X	X	X		X	X	X	SP,S,F	X	X	34-37	2	LS-16
Water quality	X	X	X	X	X	X			SP,S,F	X	X	38-42	2	LS-17
Elevations													0	
Dimensions													0	
Depth	X	X	X	X	X	X			SP,S,F	X	X	43-45	2	
11. Dams	X	X	X	X		X		X	SP,S,F	X	X	7,35	2	LS-17
Construction material													0	
Height													0	
Length													0	
Type													0	
12. Swamps	X	X	X	X		X	X	X	SP,F,S	X	X	1,46	2	
Area													0	
Direction of current													0	

CARTOGRAPHIC AND TERRAIN REQUIREMENTS	MAP AND CHART SPECIFICATIONS[1]									LANDSAT SYSTEMS - 1, 2														
						HYDROGRAPHIC CHARTS				GEOGRAPHIC[2] REGIONS				CHANNELS[3] EMPLOYED					DATA[5] TYPE					
MAP ELEMENT	CITY MAPS	TOPOGRAPHIC 1:50,000	JOINT OPERATIONS GRAPHIC 1:250,000	DIGITAL RADAR LANDMASS SIMULATOR (DRLS)	SPECIAL MAP PRODUCTS	1:50,000	1:100,000	1:250,000	OPERATIONAL NAVIGATION CHART 1:1,000,000	ARCTIC	TEMPERATE	DESERT	TROPIC	4	5	6	7	SEASONAL AND/OR REPETITIVE COVERAGE[4]	IMAGERY	CCTS	REFERENCE[6]	SYSTEMS ANALYSIS CODE[7]	NOTE #[8]
13. Ice and Snow Fields		S	S	S	S	S	S	S	S	X	X				X	X	X	F,W,SP	X	X	47-52	2	
Area				S	S	S	S	S	S													0	
Crevasses		P	P	P	S				P													0	
14. Swimming Pools	S	P		S	S																	0	
Dimensions	S			S	S																	0	
15. Reservoirs	S	S	S	S	S				S	X	X	X	X		X	X	X	W,SP,S,F	X	X	1,26,34 36	1	
Elevations	S	S	S	S	S				S													0	
Area				S	S				S													0	
Depth	P				S					X	X	X	X	X	X			SP,S,F	X	X	43-45	1	
16. Aquaducts	S	S	S	S	S				S	X	X	X	X		X	X	X	SP,W,F	X	X	None	1	LS-18
Size	P			S	S																	0	
Capacity	P				S																	0	
Construction material				S	S																	0	
17. Tidal Flats	S	S	S	S	S	S	S	S	S	X	X	X	X	X	X	X	X	SP,W,S,F	X	X	53-57	2	LS-19
Slope					S																	0	
Length	S	S	S	S	S	S	S	S	S													0	

CARTOGRAPHIC AND TERRAIN REQUIREMENTS	MAP AND CHART SPECIFICATIONS[1]									LANDSAT SYSTEMS - 1, 2														
						HYDROGRAPHIC CHARTS				GEOGRAPHIC[2] REGIONS				CHANNELS[3] EMPLOYED					DATA[5] TYPE				
MAP ELEMENT	CITY MAPS	TOPOGRAPHIC 1:50,000	JOINT OPERATIONS GRAPHIC 1:250,000	DIGITAL RADAR LANDMASS SIMULATOR (DRLS)	SPECIAL MAP PRODUCTS	1:50,000	1:100,000	1:250,000	OPERATIONAL NAVIGATION CHART 1:1,000,000	ARCTIC	TEMPERATE	DESERT	TROPIC	4	5	6	7	SEASONAL AND/OR REPETITIVE COVERAGE[4]	IMAGERY	CCTS	REFERENCE[6]	SYSTEMS ANALYSIS[7] CODE	NOTE #[8]
18. Reefs		S	S	S	S	S	S	S	S	X	X	X	X	X			X	SP,S,F	X	X	56,57	2	
Length		S	S	S	S	S	S	S	S	X	X	X	X	X			X	SP,S,F	X	X	56,57	2	
Depth		P	P		S	S	S	S		X	X	X	X	X			X	SP,S,F	X	X	56,57	2	
19. Rocky Ledges		S	S	S	S	S	S	S	S													0	
20. Rocks		S	S	S	S	S	S	S	S													0	
Bare		S	S	P	S	S	S	S	S													0	
Awash		S	S	P	S	S	S	S	S	X	X	X	X	X			X	SP,F,S	X	X	43-45	1	LS-20
Sunken		S	S	P	S	S	S	S	S	X	X	X	X	X			X		X	X	43-45	1	LS-21
21. Sunken Wrecks		S	S		S	S	S	S	S													0	
22. Near Shore Bathymetry		S	S		S	S	S	S		X	X	X	X	X			X	SP,F,S	X	X	43-45	2	
23. Near Shore Ice Conditions					S					X	X				X		X	W	X	X	None	1	
24. Water Depth		S	P		S	S	S	S		X	X	X	X	X	X		X	SP,S,W,F	X	X	43-45	2	
25. Breaker Line		S	P		S	S	S	S		X	X	X	X			X	X		X		None	2	
26. Kelp Beds		S	P		S	S	S	S		X	X	X	X			X	X		X	X	None	1	
27. Shoals		S	S	S	S	S	S	S	P	X	X	X	X	X	X				X	X	56,57,58	2	
28. Current		S	P		S	S	S	S		X	X	X	X		X	X	X		X	X	58-61	2	
Type			P		S	S	S	S														0	

CARTOGRAPHIC AND TERRAIN REQUIREMENTS	MAP AND CHART SPECIFICATIONS[1]									LANDSAT SYSTEMS - 1, 2													
						HYDROGRAPHIC CHARTS				GEOGRAPHIC[2] REGIONS				CHANNELS[3] EMPLOYED					DATA[5] TYPE				
MAP ELEMENT	CITY MAPS	TOPOGRAPHIC 1:50,000	JOINT OPERATIONS GRAPHIC 1:250,000	DIGITAL RADAR LANDMASS SIMULATOR (DRLS)	SPECIAL MAP PRODUCTS	1:50,000	1:100,000	1:250,000	OPERATIONAL NAVIGATION CHART 1:1,000,000	ARCTIC	TEMPERATE	DESERT	TROPIC	4	5	6	7	SEASONAL AND/OR REPETITIVE COVERAGE[4]	IMAGERY	CCTS	REFERENCE[6]	SYSTEMS ANALYSIS CODE[7]	NOTE #8
Velocity			P		S	S	S	S														0	
29. Marsh		S	S	S	S	S	S	S	S	X	X		X		X	X	X	SP,S	X	X	1,46	2	
Area			S	S	S	S	S	S	S													0	
Depth					S																	0	
30. Peat Bogs		S	P	P	P				P	X	X				X	X	X	SP,S, W	X	X	None	2	LS-22 C-7
Area			S	P	P																	0	
31. Harbors		S	S	S	S	S	S	S	S	X	X		X		X		X		X	X	57	2	
Structures		S	S	S	S	S	S	S	S	X	X		X		X	X	X		X	X	None	1	LS-6
Channel location		P				S	S	S		X	X		X	X	X				X	X	57	2	
Channel depth		P				S	S	S		X	X		X	X	X				X	X	43-45	2	
Width		P				S	S	S		X	X		X	X	X				X	X	57	1	
Obstructions		P				S	S	S														0	
32. Shoreline Delineation	S	S	S	S	S	S	S	S	S	X	X	X	X		X		X		X	X	1,46,57	2	
33. Islands		S	S	S	S	S	S	S	S	X	X	X	X		X		X		X	X	1,46,57	2	
34. Deltas		S	S	S	S	S	S	S	S	X	X	X	X		X		X		X	X	1,46,57	2	

CARTOGRAPHIC AND TERRAIN REQUIREMENTS	MAP AND CHART SPECIFICATIONS[1]									LANDSAT SYSTEMS - 1, 2														
						HYDROGRAPHIC CHARTS				GEOGRAPHIC[2] REGIONS				CHANNELS[3] EMPLOYED					DATA[5] TYPE				
MAP ELEMENT	CITY MAPS	TOPOGRAPHIC 1:50,000	JOINT OPERATIONS GRAPHIC 1:250,000	DIGITAL RADAR LANDMASS SIMULATOR (DRLS)	SPECIAL MAP PRODUCTS	1:50,000	1:100,000	1:250,000	OPERATIONAL NAVIGATION CHART 1:1,000,000	ARCTIC	TEMPERATE	DESERT	TROPIC	4	5	6	7	SEASONAL AND/OR REPETITIVE COVERAGE[4]	IMAGERY	CCTS	REFERENCE[6]	SYSTEMS ANALYSIS CODE[7]	NOTE #[8]
D. RELIEF AND SURFICIAL MATERIALS																							
1. Sand Dunes		S	S	S	S				P	X	X	X	X		X	X	X		X	X	1,57,62	2	
Type		S	S	S	S				P													0	
Area				S	S				P													0	
2. Gravel Beds		S	S	S	S				P	X	X	X			X	X	X		X	X	None	1	LS-23
3. Landforms		S	S	S	S	S	S	S	S	X	X	X	X		X	X	X		X		63	2	LS-24
Escarpments		S	S	S	S	S	S	S	S	X	X	X	X		X	X	X		X		63	2	
Depressions		S	S	S	S				P	X	X	X	X		X	X	X		X		63	2	
Buttes		S	S	S	S	S	S	S	S	X	X	X	X		X	X	X		X		63	2	
Slopes					S				S	X	X	X	X		X	X	X		X		63,64	2	
Contours		S	S	S	S	S	S	S	S													0	
4. Relief									S	X	X	X	X		X	X	X	F,W, SP	X		63,64	1	
5. Soil Type				S	S					X	X	X	X		X	X	X	F,W,SP	X	X	29,65-68	2	
6. Soil Moisture				S	S																	0	
7. Slope Intercept					S																	0	
8. Microrelief					S																	0	
9. Bedrock Type				S	S					X	X	X	X	X	X	X		F,W,SP	X	X	69-72	1	

CARTOGRAPHIC AND TERRAIN REQUIREMENTS	MAP AND CHART SPECIFICATIONS[1]									LANDSAT SYSTEMS - 1, 2													
						HYDROGRAPHIC CHARTS				GEOGRAPHIC[2] REGIONS				CHANNELS[3] EMPLOYED					DATA[5] TYPE				
MAP ELEMENT	CITY MAPS	TOPOGRAPHIC 1:50,000	JOINT OPERATIONS GRAPHIC 1:250,000	DIGITAL RADAR LANDMASS SIMULATOR (DRLS)	SPECIAL MAP PRODUCTS	1:50,000	1:100,000	1:250,000	OPERATIONAL NAVIGATION CHART 1:1,000,000	ARCTIC	TEMPERATE	DESERT	TROPIC	4	5	6	7	SEASONAL AND/OR REPETITIVE COVERAGE[4]	IMAGERY	CCTS	REFERENCE[6]	SYSTEMS ANALYSIS[7] CODE	NOTE #[8]
10. Landslide Areas		P		P	S					X	X	X	X		X	X	X	F,W	X	X	30	2	
11. Mountain Passes		S	S	S	S	P	P	P	S	X	X	X	X		X	X	X		X		63,64	2	
12. Mine Dumps and Tailings		S	S	S	S	S	S	S	S	X	X	X	X		X	X	X		X	X	20,21,22	2	
13. Distorted Areas		S	S	S						X	X	X	X		X	X	X		X	X	30	2	C-8
E. VEGETATION.																							
1. Woodland	S	S	S	S	S	S	S	S	S	X	X	X	X		X	X	X		X	X	46,73,74	3	C-9
2. Scattered Trees		S	S	S	S	P	P	P														0	
3. Tree Stem Spacing	P			S	S																	0	
4. Tree Crown Diameter					S																	0	
5. Tree Stem Diameter					S																	0	
6. Tree Height		S	S	S	S																	0	
7. Percent Crown Cover	S	S	S	S	S																	0	
8. Scrub	P	S	S							X	X	X	X		X	X	X	SP,F,W	X	X	1	2	LS-25
9. Orchards	P	S	S	P	S	S	S	P			X		X		X	X	X	S	X	X	None	1	LS-26
10. Plantations	P	S	P	P	S	S	S	S	P		X		X		X	X	X	S	X	X	None	1	LS-26

MAP ELEMENT	CITY MAPS	TOPOGRAPHIC 1:50,000	JOINT OPERATIONS GRAPHIC 1:250,000	DIGITAL RADAR LANDMASS SIMULATOR (DRLS)	SPECIAL MAP PRODUCTS	HYDROGRAPHIC CHARTS 1:50,000	HYDROGRAPHIC CHARTS 1:100,000	HYDROGRAPHIC CHARTS 1:250,000	OPERATIONAL NAVIGATION CHART 1:1,000,000	GEOGRAPHIC REGIONS[2] ARCTIC	TEMPERATE	DESERT	TROPIC	CHANNELS[3] EMPLOYED 4	5	6	7	SEASONAL AND/OR REPETITIVE COVERAGE[4]	DATA[5] TYPE IMAGERY	CCTS	REFERENCE[6]	SYSTEMS ANALYSIS CODE[7]	NOTE #[8]
11. Vineyards	P	S	P	P	S				P													0	
12. Mangrove	P	S	S	P	S	S	S	S	P		X	X	X		X	X	X		X	X	75	2	
13. Tropical Grass	P	S	S	P							X		X		X	X	X		X	X	None	2	
14. Isolated Trees	P	P	P		P																	0	C-10
15. Clearings	S	S	S	S	S				P	X	X	X	X		X	X	X	S,W	X	X	1,76	2	C-11
Power lines	S	S	S	S	S				S	X	X		X		X	X	X	S,W	X	X	1,7,26	2	
Pipelines	S	S	S	S	S				P													0	
Fire breaks	S	S	P	S	S				P	X	X	X	X		X	X	X		X	X	1,7,26, 76	2	C-12
16. Oasis	S	S	S	P	S				P			X			X	X	X		X	X	None	1	
17. Hedge Rows		S	S		S				P													0	
18. Grass Areas	S	P		S	S					X	X	X	X		X	X	X	S,W	X	X	10-15	2	
Pastures	S	P		S	S					X	X		X		X	X	X	S,W	X	X	10-15	2	
Fields		P		S	S					X	X	X	X		X	X	X	S,W	X	X	10-15	2	

CARTOGRAPHIC AND TERRAIN REQUIREMENTS — MAP AND CHART SPECIFICATIONS[1] — LANDSAT SYSTEMS - 1, 2

DISCUSSION AND SUMMARY

LANDSAT 1 and 2.

Multispectral Scanner. The analysis of the MSS system, as presented in table 3 and summarized in table 4, indicates that this sensor cannot be considered as a primary collection system for cartographic and terrain information. Although the geometric accuracy of the scanner is adequate for map scales from 1:1,000,000 through 1:250,000,[5] the ground resolution limitations are below that required for classification of many of the map elements. Of the five major Map Element Categories considered in this analysis, those elements contained in the Cultural Category (B, table 3) have the poorest classification rate by either human or automated means. The small size of many of these elements (in relation to the MSS resolution capabilities) make them difficult to detect even on standard aerial photography. In contrast, the MSS data has considerable capability for acquiring information in the Hydrologic Category (C, table 3). The reasons for this high classification rate include (1) The unusually high contrast ratio that these features have with their background; (2) Many of these features form linear patterns; (3) The hydrologic features, such as drainage channels, are enhanced by either shadows or vegetation; and (4) Channels 4 and 5 have considerable water penetration capability.[6] The MSS capability for water penetration can be enhanced even further because the dynamic range of Channels 4 and 5 can be increased by command from the NASA Control Center.

In addition to the standard map and chart products required by DOD, there is a series of Special Map Products that include such graphics as cross-country mobility and engineering soils. The list of terrain features required for these thematic maps is extensive and difficult to obtain by any method other than ground survey. When analyzing LANDSAT capabilities to meet the requirements for these maps on a feature-by-feature basis, it becomes apparent that the LANDSAT systems do not have suitable resolution to obtain the majority of these features. If, however, the LANDSAT data were to be employed in a multistage sampling technique[7] where these data are used with conventional remote sensor imagery and a ground survey, the utility of the LANDSAT data would be greatly increased.

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[5]J. C. Trender and S. U. Nasca, "Test on the Mapping Application of LANDSAT Imagery," Paper presented at the 13th Congress of the International Society of Photogrammetry, Helsinki, Finland, 1976.

[6]J. C. Hammack, "LANDSAT Goes to Sea," Paper presented at the Pecora Symposium, Sioux Falls, SD, 1976.

[7]P. G. Langley, "New Multistage Sampling Techniques Using Space and Aircraft Imagery for Forest Inventory," Proceedings of the Sixth International Symposium on Remote Sensing of Environment, Ann Arbor, MI, 1969.

Table 4. Summary of LANDSAT Analysis by Detection Code

MAP TYPE	NO. MAP REQUIREMENTS	SYSTEMS ANALYSIS CODE* 0	1	2	3
Topographic 1:50,000	169	43	22	34	1
Joint Operations Graphic 1:250,000	164	44	24	31	1
Hydrographic 1:100,000	93	35	19	45	1
Operational Navigation Chart 1:1,000,000	131	43	22	34	1
Special Maps	284	60	15	24	1

*Percent of total number of map requirements.

The greatest benefits can be derived from the MSS data when it is employed in one or more of the following applications:

1. Delineating large homogeneous areas, e.g., land use maps.

2. Detecting and delineating reefs and underwater features.

3. Detecting large geologic structures and features, such as faults, lineations, surficial deposits,[8] and domes.

4. Employing multistage sampling techniques.

5. Conducting crop inventories.

With the exception of crop inventories, the accuracy of area determinations obtained from LANDSAT data are difficult to acquire from the literature. The accuracies reported for crop inventories range from approximately 48 to 98 percent.[9] The accuracy of these inventories are highly dependent on the type and amount of ground data available for inventory design.

One of the problems in analyzing a remote sensor system from technical literature occurs, for example, when an attempt is made to determine the exact resolution limitation of the MSS system. Lakes, small ponds (one pixel in area), and rivers (less than one pixel wide) can easily be identified on Channels 6 and 7 because of the high contrast ratio these features usually have with their background. Concrete roads and runways (less than one pixel wide) can also be readily detected because of their high contrast ratio and because they are linear features. Consistently, linear features, such as roads, railroads, etc., were reported in the literature as being classifiable from MSS imagery. Actually, the authors were able to detect the linear feature where it traversed a forested area because a right-of-way had been cleared to a width of 60 to 100 meters. Once detected in this manner, the authors then used a map or a priori knowledge to classify the feature as a road, railroad, etc.

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[8]Follestad and D. W. Levandowski, "Analysis of LANDSAT-1 Data for Mapping of Surficial Materials," Paper presented at the 13th Congress of the International Society of Photogrammetry;" Helsinki, Finland, 1976.

[9]M. E. Bauer and J. E. Cipra, "Identification of Agricultural Crops by Computer Processing of ERTS MSS Data," Symposium on Significant Results Obtained from the Earth Resources Technology Satellite, Vol. I, 1973, pp. 205-212.

In attempting to analyze the relative merits of machine versus human interpretation methods, it was learned that the majority of the work accomplished to date with LANDSAT data has been with imagery and conventional interpretation techniques. The reasons for the prevalance of the conventional interpretation technique appears to be based on a number of factors. These factors include the accessibility and low cost of the imagery, the reasonably low cost of the necessary viewing equipment, and the availability of funds from NASA (prior to 1974) that permitted a large number of individuals to utilize MSS imagery in their research efforts. Automated data extraction is needed because of the increased information available by using the digital data, the increase in the efficiency of data extraction that these procedures provide, and the decrease in cost of reproducing digital tapes over photographic reproduction of MSS imagery.

In general, there are two major types of data analysis procedures or clustering methods employed for automated extraction of digital MSS data, supervised and unsupervised classification. The supervised classification procedure provides more efficient use of computer time, but its success depends on a requirement for a priori information or ground truth, called training samples. In this procedure, homogeneous land-use training areas (samples) within the scene are identified and specified, through operator interaction, by using information collected from either ground surveys, aerial photography, or existing maps. Once these training areas have been located and identified, the computer is then programmed to stratify and classify the entire scene according to the multispectral statistical data derived from the learning sets. In this method of analysis, the effective use of computer time can be enhanced by stratifying only those land-use classifications of particular interest, for example cultivated areas, and by placing all other scene areas into a single category.

The unsupervised classification procedure does not require the input of homogeneous training samples or prior correlation of ground truth in the interpretation of the data. This procedure relies on automated multispectral statistical analysis methods to determine the existence and location of homogeneous areas (clusters) within the scene. The classification of any clusters located by the computer system must then rely on the use of collateral information, such as maps, airphotos, etc., but excludes the need for ground truth information prior to the data extraction procedures.

With the exception of a limited number of research reports,[10] the type of automated procedures used at the present time rely totally on the spectral data available in the scene and ignore both the spatial

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[10] R. M. Haralick and K. S. Shanmugan, "Combined Spectral and Spatial Processing of ERTS Imagery Data," Remote Sensing of the Environment, Vol. 3, No.1, 1974, pp.3-13.

and contextual information that exists within the MSS data. If this information could be employed as it is by image interpreters using conventional remote sensor imagery, the accuracy of MSS derived data would be improved and the amount and type of information achievable would be increased.

An analysis of the LANDSAT MSS system would not be complete without mention of the work accomplished by countries other than the United States. Countries such as Canada and Australia[11] have large land areas that are undeveloped and that have been mapped at very small scales. These countries have placed considerable emphasis of the use of MSS data in conjunction with the small scale maps to produce maps at larger scales and to refine or update existing maps. Apparently, a correlation exists between the amount of LANDSAT data used and the amount of land area within a country that is in need of mapping. If such countries had available elevation data[12] similar to that available in the U.S. and if the total effect of the sun angle, the atmosphere,[13] and the terrain slope on the MSS imagery were known and understood, this imagery would probably be used more than it is at the present time.

LANDSAT 3. The third satellite in the NASA experimental program will be launched in September 1977 and will contain a five-channel MSS, a two-camera RBV, and a Data Collection System, receiver and transmitter.[14] The MSS will contain a fifth band, Channel 8, that operates in the emitted or thermal infrared range of the spectrum (10.4 to 12.6 micrometers) with a ground pixel size of 238 by 238 meters (780 by 780 feet). The RBV system will contain two identical cameras that provide a panchromatic response (0.50 to 0.75 micrometers) and are aligned to view adjacent 98- by 98-kilometer ground area with a 14-kilometer sidelap. Two successive frame pairs will nominally cover the same ground areas as an MSS frame. The ground resolution cell of these cameras have been increased by a factor of two, covering a ground area of 40 by 40 meters.

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[11] J. C. Trender and S. U. Nasca, "Test on the Mapping Application of LANDSAT Imagery," Paper presented at the 13th Congress of the International Society of Photogrammetry, Helsinki, Finland, 1976.

[12] Available at the National Cartographic Information Center, U.S. Geological Survey, Reston, VA 22092.

[13] J. Potter and M. Shelton, "Effect of Atmospheric Haze and Sun Angle on Automatic Classification of ERTS-1 Data," Proceedings of the 9th International Symposium on Remote Sensing of Environment, April 1970.

[14] NASA Applications Notice, AN-OA, 76-B, Inputs Requested from Earth Resources Remote Sensing Data Users Regarding LANDSAT-C Mission Requirements and Data Needs, 1976.

In analyzing the increased capabilities of this system in comparison with LANDSAT 1 and 2, in the original NASA program the RBV cameras were designed to be the primary source of imagery and not the MSS. Because the RBV system in LANDSAT 3 will have twice the resolution capability of the MSS, it may prove to be the sensor most utilized, although it does not have a multispectral response capability. The panchromatic response of the RBV system precludes the use of existing software methods now used for image data extraction. However, the increased resolution capability of the RBV should increase the utility of this subsystem for acquisition of cartographic and terrain data. The 40- by 40-meter ground resolution cell, however, is believed to be too large to create a significant change in this system's capability for acquisition of those map elements in the Cultural and Vegetation Categories (table 3). The RBV imagery would be adequate for determining the amount of land area covered by flood, but unless the distribution of this imagery can be reduced to near real-time, it will not be totally effective for this purpose.

The thermal infrared band, Channel 8, can provide for day/night imagery, better delineation of urban and built-up areas, and an improved method of separating various types of agricultural crops. The varying planting and growing characteristics of corn, for example, are expected to create a different pattern on the thermal infrared imagery than wheat. A field of corn would create a higher temperature pattern than a field of wheat because the planting density of corn before reaching maturity would expose more bare soil, thus creating a more efficient surface for ab rbing and reradiating solar energy. As with the RBV system, Channel 8 should provide increased reliability for flood area estimation, not only from the standpoint of detecting the thermal image of the flood waters, but from the day/night image acquisition capability inherent with this thermal infrared system.

Presently, concern has been expressed within the user community over the method of data reduction and the type of image products that NASA intends to reproduce and distribute from LANDSAT 3. Although these changes in data reduction methods may appear to be based primarily on cost reduction, the fact remains that digital data will provide considerably more information than is available on film, and it can be duplicated with higher standards of image data reproduction. The true evaluation of the data reduction methods and the increased capabilities of LANDSAT 3 cannot be ascertained, of course, until this system becomes operations.

LANDSAT 4. This system, now being planned for operation in the 1980's, will be the first nonexperimental satellite in the NASA Earth Resources Program. It will contain an MSS, identical in design to those employed on LANDSAT 1 and 2, and a Thematic Mapper. The major improvements designed into this sensor system include a reduction in the size of the ground resolution cell of Channels 1 through 6 and a change in the spectral sensitivity characteristics of Channels 1 through 5 (table 2). The Return Beam Vidicon Cameras and the Data Collection System employed on the earlier satellites will not be available on LANDSAT 4.

The improved resolution and spectral response of the Thematic Mapper should, in general, greatly enhance the total capabilities of LANDSAT 4, particularly for agricultural inventories and for detection of underwater features. This system, however, still does not provide for using spatial, contextual, or three-dimensional imagery. Although Channel 6 (the thermal infrared channel) may provide surrogate spatial data, the total reliance of this system on spectral data has to be considered a highly limiting factor in analyzing the capabilities of this system. For the specific terrain and cartographic categories of Culture and Hydrography, the 30-meter (98.4 feet) ground resolution cell is believed to be too large for accurate identification, measurement, and classification of these categories for map scales larger than 1:100,000.[15] For example, determining the width of small streams and rivers are important requirements for most types of military maps. In addition, the cultural requirements for Military City Maps are particularly strenuous, requiring the classification of building use and the measurement of street widths. All of these requirements are difficult, if not impossible, to obtain from higher resolution, cartographic aerial photography. Often, these map elements must be acquired through either technical literature or ground survey methods. However, imagery obtained with the Thematic Mapper (TM) used in conjunction with conventional aerial photography should provide a more advantageous and efficient method of producing military thematic graphics, such as vegetation maps, than the use of either single source of aerial imagery.

Many of the problems associated with correcting, reproducing, and using LANDSAT 4 imagery will have been resolved by the time this system becomes operational, since the data reduction procedures will be similar to those employed for LANDSAT 3. The RBV imagery from LANDSAT 3 will also provide a method for evaluating the increased resolution of the TM. Although, this RBV imagery is limited to a panchromatic type of spectral response and a ground resolution cell of 40 by 40 meters, it will permit a semi-quantitative evaluation of the imagery obtained with the Thematic Mapper. By combining both an MSS and TM on the same satellite, NASA has provided not only a means of adapting MSS data reduction algorithms to TM algorithms but also the data needed for comparing the capabilities of these two sensors.

CONCLUSIONS

<u>LANDSAT 1 and 2</u>.

1. Multispectral scanner imagery can provide cartographic and terrain data, compatible with National Map Accuracy Standards for map and chart scales of 1:1,000,000 through 1:100,000.

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[15]Based on the assumption that registration and position accuracies will ± 15 meters.

2. The resolution of the MSS imagery is believed to be inadequate for classification of the majority of map elements contained in the Culture, Vegetation, and Hydrographic categories.

3. MSS imagery obtained from Channels 4, 5, and 7 provide an effective method for updating existing medium and small scale Hydrographic Charts.

4. The most effective use of LANDSAT data is in the digital form, employed with conventional imagery in a multistage sampling procedure.

<u>LANDSAT 3</u>.

1. The improved resolution of the RBV cameras will increase the utility for this type of imagery by the user community.

2. The thermal infrared band, Channel 6, will provide an increased capability for flood damage assessment and agricultural inventories.

<u>LANDSAT 4</u>.

1. The Thematic Mapper of LANDSAT 4 will improve the general capabilities of this system, but the resolution is believed to be inadequate for many of the cultural and hydrographic features required on military maps.

2. The improved geographic positioning accuracy designed into the Thematic Mapper may provide an effective method for producing planimetric maps at a scale of 1:50,000.

3. The improved throughput time and spectral response of LANDSAT 4 imagery will increase the capabilities of this system for flood damage estimates, water depth penetration, and agricultural inventories.

Appendix A. LANDSAT Systems Notes

LS-1. Many long linear features, such as roads, canals, and causeways, are detectable on LANDSAT imagery even though their width is smaller than a ground resolution cell. If the long axis of the feature runs parallel to the scan lines, the detection rate may be increased. The feature/background contrast ratio also affects the detectability of linear features.

LS-2. In the northern United States, snow cover enhances many features that would normally be undetectable. Roads and streets that have had the snow cover removed often become detectable because of the resulting increase in contrast.

LS-3. Large bridges can often be detected if they are oriented on the image parallel to the scan lines. The contrast provided between Channels 5 and 7 can also be used to detect bridges constructed over large bodies of water.

LS-4. Long causeways can be detected but have to be identified from collateral information.

LS-5. Railroads and other linear features are detectable but are usually identified from collateral information. Railroad gauge is often standardized throughout a nation.

LS-6. Buildings can be detected based on their area and the contrast of the roof material with the background.

LS-7. Large trailer parks often provide a detectable pattern. Identification would have to rely on ground truth.

LS-8. Populated areas often have the same spectral response as lakes and ponds. Detection and identification can usually be made on the shape of the image pattern.

LS-9. Rural settlements greater than 40 hectares in area have been detected and properly identified.

LS-10. Powerlines that traverse wooded areas can be detected from the cleared right-of-way. Identification of these features depends, most often, on collateral information. These features are not detectable when they traverse bare soil or unforested fields.

LS-11. Large tank farms (greater than 30 to 40 hectares) should be detectable by pattern. Identification would be dependent on collateral information.

LS-12. Mines and mining operations that create a large disturbed area on the terrain are detectable with considerable collateral information.

LS-13. Streams and small rivers 20 to 50 meters in width have been detected. Drainage channel patterns can also be detected when enhanced by either snow or vegetation.

LS-14. Bank material or soil type can often be identified from adjacent soil patterns.

LS-15. Flood plains dependent on size can be identified by change in land-use pattern, change in vegetation type, or change in percent of soil moisture.

LS-16. Bodies of water, because of their high contrast, are easily detected on both imagery and data tapes. Lakes as small as one pixel size have been detected from CCTS, and procedures have been developed to determine lakes that occupy only partial areas of picture elements.

LS-17. Dams can be located by the detection of the linear terminations of water bodies.

LS-18. Aquaducts are linear features that can often be detected by their high contrast and the detection of their rights-of-way.

LS-19. Tidal flats can often be detected from the contrast ratios between Channels 5 and 7. Land use and changes in vegetation patterns are also helpful in detecting these features.

LS-20. Depending on size, area occupied, and the turbidity of the water, these features can be detected by the same procedures used for reefs.

LS-21. Disruption of the surface may create a disturbed pattern on the water surface that would be large enough to detect.

LS-22. The detection of peat bogs would rely on change in land-use pattern and spectral differences between the bog pattern and surrounding type of vegetation.

LS-23. Gravel beds of appreciable size (4 to 5 acres) should be detectable on the basis of their usually high reflectivity.

LS-24. Above 40° north or south latitude, there is enough convergence of the LANDSAT flightlines to provide stereo viewing of the imagery. In addition, in areas of high relief drainage channels can be used to provide topographic information.

LS-25. The detection of shrub species and other lower forms of vegetation is highly dependent on the use of collateral information.

LS-26. The patterns formed by large orchards should be detectable on LANDSAT imagery, but identification and classification would be dependent on ground truth or other forms of collateral information.

Appendix B. Cartographic Notes

C1. Road Classification. Roads are classified as follows for medium and large scale maps:

CLASSIFICATION CATEGORY*	WIDTH
All weather, hard surface, two or more lanes.	Two lanes - at least 18 ft. (5.5m) and less than 27 ft. (8.2m). More than 2 lanes - more than 27 ft. (82m).
All weather, loose or light surface, two or more lanes.	Two lanes - at least 18 ft. (5.5m) and less than 27 ft. (8.2m). More than 2 lanes - more than 27 ft. (8.2m).
All weather, hard surface, one lane.	At least 8 ft. (2.5m) and less than 18 ft. (5.5m).
Fair or dry weather, loose surface.	At least 8 ft. (2.5m).
Tracks	At least 5 ft. (1.5m) and less than 8 ft. (2.5m).
Trails	Less than 5 ft. (1.5m)

C2. City Streets. Through routes and numbered routes within built-up areas have to be identified and classified. A random selection of streets are measured and the widths annotated.

C3. The Digital Radar Landmass Simulator (DRLS) requirements include those terrain features that will provide a strong radar response or return, in this regard, directionality of each highly significant radar feature is noted in manuscript form. These features are noted on large scale maps (1:75,000) when they are longer than 0.10 inch (2.5 millimeters) at scale, and 10 feet (3 meters) in actual height.

C4. The railroad yard size requirements for the JOG and ONC chart series are the same in width (5 tracks) but vary in length. To be indicated on the JOG series, a railroad yard must be equal to or greater than 2,000 feet (609 meters). While the ONR map requires only 1,000 feet (305 meters).

C5. The requirements for all maps separate streams into the following classifications: perennial, intermittent, disappearing, and braided.

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*Department of Defense, TPC TM S-1, "Map Specifications," October 1971.

The classifications often require sequential photography and are extremely difficult to obtain from machine processing in comparison to open water features.

C6. Perennial streams are shown on large and medium scale maps as two lines if they are greater than 0.02 inch (0.50 millimeters) at map scale and a single line if they are less than this distance.

C7. Peat bogs are areas where peat is being harvested for fuel.

C8. Distorted areas are indicated by area boundary and are used, for example, to locate large boulder fields and lava flows.

C9. Wooded areas are shown on medium and large scale maps if they are at least 10 feet in height (3 meters), have an appropriate crown density of 50 percent and occupy an area greater than 0.1 by 0.1 inch at map scale (2.50 by 2.50 millimeters). Narrow strips of vegetation are not shown unless they are greater than 0.05 inch in width at map scale (1.25 millimeters), serve as a landmark feature, or offer concealment along a road.

C10. Isolated trees are not shown except when they serve as a landmark feature.

C11. Clearings less than the equivalent area of 0.10 by 0.10 inch (2.50 by 2.50 millimeters) are not shown on medium and large scale maps.

C12. On large scale maps (greater than 1:75,000), fire breaks less than 30 feet (9 meters) in width are shown as a minimum clearing 0.02 inch (0.50 millimeters) in width or are platted to scale.

BIBLIOGRAPHY

1. Clapp, J. L. and R. W. Kiefer, "The Application of ERTS-Derived Information to the Regional Landuse Planning Process," Proceedings of the American Society of Photogrammetry, Fall Convention, Washington, D. C., pp. 72-87, 1974.

2. Thie, Jean and C. Wachmann, "Remote Sensing for Environmental Monitoring and Impact Assessment," ISP Commission VII Proceedings of Symposium on Remote Sensing and Photo Interpretation, Banff, Alberta, 1974.

3. De Gloria, S. D., et al., "Utilization of High Altitude Photography and Landsat-1 Data for Change Detection and Sensitive Area Analysis," Proceedings of Tenth International Symposium on Remote Sensing of Environment, Vol. I, pp. 359-368, 1975.

4. Todd, W., et al., "Preparation of Urban Land Use Inventories by Machine Processing of ERTS MSS Data," Symposium on Significant Results Obtained from the Earth Resources Satellite, Vol. 2, pp. 1031-1040, 1973.

5. Oswald, E. T., "Evaluation of ERTS Imagery for Vegetation Interpretation in British Columbia," Canadian Surveyor, Vol. 28, No. 2, pp. 147-154, 1974.

6. Kirby, Charles, "Temporal Analysis of ERTS Imagery in the Boreal Forest Region," Canadian Surveyor, Vol. 28, No. 2, pp. 142-146, 1974.

7. Lee, Y. J., "Monitoring Forest Management Operations," Canadian Surveyor, Vol. 28, No. 2, pp. 135-144, 1974.

8. Borden, F. Y., "The Use of the Temporal Dimension in Classifying and Mapping ERTS-1 MSS Data," Symposium on Significant Results Obtained from the Earth Resources Satellite, Vol. 2, pp. 1059-1066, 1973.

9. Ellefsen, R., et al., "New Techniques in Mapping Urban Land Use and Monitoring Change for Selected U. S. Metropolitan Areas: An Experiment Employing Computer-Assisted Analysis of ERTS-1 MSS Data," ISP Commission VII Proceedings of Symposium on Remote Sensing and Photo Interpretation, Vol. 1, pp. 51-63, 1974.

10. Taylor, W. C., et al., "Survey of Recent Resource Applications in Michigan," Proceedings of Tenth International Symposium on Remote Sensing of Environment, 1975.

11. Bauer, M. E. and J. E. Cipra, "Identification of Agricultural Crops by Computer Processing of ERTS MSS Data," Symposium on Significant Results Obtained from the Earth Resources Satellite, Vol. I, pp. 205-212, 1973.

12. Wiegand, C. L., et al., "Vegetation Density as Deduced from ERTS-1 MSS Response," Third Earth Resources Technology Satellite-1 Symposium, Vol. 1, pp. 93-116, 1973.

13. Welch, R. and C. W. Pannell, "LANDSAT Investigations of Recent Urban Land Use Changes in Northeast China," Proceedings of the Tenth International Symposium on Remote Sensing of Environment, Vol. I, pp. 373-382, 1975.

14. McKim, H. L., et al., Land Use/Vegetation Mapping in Reservoir Management Merrimach River Basin, U. S. Army Cold Regions Research and Engineering Laboratory, Special Report 233, 1975.

15. Alexander, R. H., "Land Use Classification and Change Analysis Using ERTS-1 Imagery in CARETS," Symposium on Significant Results Obtained from the Earth Resources Satellite, Vol. 1, pp. 923-930, 1973.

16. Lundelius, M. A., et al., "A Comparison of Land Use Determinations Using Data from ERTS-1 and High Altitude Aircraft," Symposium on Significant Results Obtained from the Earth Resources Satellite, Vol. 2, pp. 1041-1047, 1973.

17. Dornback, J. E., "Landuse Classification with ERTS-1 Data in the Houston Area Test Site," Proceedings of the American Society of Photogrammetry, Fall Convention, Washington, D. C., pp. 88-98, 1974.

18. Colvocoresses, A. P.,"Evaluation of the Cartographic Application of ERTS-1 Imagery," The American Cartographer, Vol. 2, No. 1, pp. 5-18, 1975.

19. Raje, S. and R. Economy, "Interactive Analysis and Evaluation of ERTS Data for Regional Planning and Urban Development. A Los Angeles Basin Case Study," Third Earth Resources Technology Satellite-1 Symposium, Vol. 1, pp. 351-369, 1973.

20. Reining, P. and D. Egbert, "Interactive Multi-Spectral Analysis of More than One Sonrai Village in Niger, W. Africa," NASA Earth Resources Survey Symposium, Vol. 1-C, pp. 1811-1821, 1975.

21. Borden, F. Y., et al., "Identification and Mapping of Coal Refuse Banks and Other Targets in the Anthracite Region," Symposium on Significant Results Obtained from the Earth Resources Satellite, Vol. 2, pp. 1067-1074, 1973.

22. Borden, F. Y., et al., "Classification and Mapping of Coal Refuse, Vegetation Cover Types, and Forest Types by Digital Processing ERTS-1 Data," Proceedings of 9th International Symposium on Remote Sensing of Environment, Vol. 1, pp. 133-161, 1974.

23. Drake, B., "Geologic Interpretation of Landsat-1 Imagery of the Greater Part of the Michigan Basin," Proceedings of the Tenth International Symposium on Remote Sensing of Environment, 1975.

24. Ahmod, M. V. and D. A. Kanter, "Mapping of Spoil Banks Using ERTS-A Pictures," Remote Sensing of Earth Resources, Vol. 2, pp. 1073-1093, 1973.

25. Hannah, J. W., G. L. Thomas, and F. Esparza, "Satellite Information on Orlando, Florida," NASA Earth Resources Survey Symposium, Vol. 1-C, 1975.

26. Russell, O. R., et al., "Applications of ERTS-1 and Aircraft Imagery to Mined Land Investigations," Remote Sensing of Earth Resources, Vol. 2, pp. 1095-1106, 1973.

27. Fleming, E. A., "Canadian Mapping Use of Landsat Imagery," Proceedings of the Tenth International Symposium of Remote Sensing of Environment, Vol. 2, pp. 1451-1456, 1975.

28. Egbert, D., et al., "Optical Data Processing Analysis of Stream Patterns Exhibited on ERTS-1 Imagery," Proceedings of the 9th International Symposium on Remote Sensing of Environment, Vol. 3, pp. 1933-1951, 1974.

29. Tueller, P. T. and G. Lorain, "ERTS-1 Evaluations of Natural Resources Management Applications in the Great Basin," Symposium on Significant Results Obtained from the Earth Resources Satellite, Vol. 1, pp. 77-86, 1973.

30. Westin, F. C. and C. J. Frazee, "LANDSAT-1 Data, Its Use in a Soil Survey Program," NASA Earth Resources Survey Symposium, Vol. 1A, pp. 67-95, 1975.

31. Moore, W. C., "Detection and Delineation of Natural Disasters: Landslides and Floods," Canadian Surveyor, Vol. 28, No. 2, pp. 180-186, 1974.

32. Morrison, R. B. and M. E. Cooley, "Assessment of Flood Damage in Arizona by Means of ERTS-1 Imagery," Symposium on Significant Results Obtained from the Earth Resources Satellite, Vol. I, pp. 755-760, 1973.

33. Hallberg, G. R., et al., "Application of ERTS-1 Imagery to Flood Inundation Mapping," Symposium on Significant Results Obtained from the Earth Resources Satellite, Vol. I, pp. 745-754, 1973.

34. Deutch, M. and F. H. Ruggles, "Mapping of the 1973 Mississippi River Floods from the Earth Resources Technology Satellite/ERTS/," Proceedings of the Symposium on Remote Sensing and Water Resources Management, Burlington, Ontario, Canada, 1973.

35. Deutsch, M. and F. H. Ruggles, "Optical Data Processing and Projected Applications of the ERTS-1 Imagery Covering the 1973 Mississippi River Valley Floods," Third Earth Resources Technology Satellite Symposium, Vol. 1, pp. 1167-1188, 1973.

36. Work, E. A., D. S. Gilmer, and A. T. Klett, "Preliminary Evaluation of ERTS-1 for Determining Number and Distribution of Prairie Ponds and Lakes," Symposium on Significant Results Obtained from the Earth Resources Satellite, Vol. I, pp. 801-807, 1973.

37. McKim, H. L., T. L. Marlar, and D. M. Anderson, The Use of ERTS-1 Imagery in the National Program for the Inspection of Dams, U. S. Army Cold Regions Research and Engineering Laboratory, Special Report 183, 1972.

38. Lockheed Electronics, Procedures Manual for Detection and Location of Surface Water Using ERTS-1 Multispectral Scanner Data, Vol. 5 Information, Correlation, and Interpretation, NASA Report CR 140219, 1973.

39. Komdratyev, K. A., et al., "An Analysis of the Earth Resources Satellite ERTS-1 Data," Remote Sensing of Environment, Vol. 2, No. 4, pp. 273-283, 1973.

40. Barker, John L., "Monitoring Water Quality from Landsat," NASA Earth Resources Survey Symposium, Vol. 1A, pp 383-418, 1975.

41. Blackwell, C. J. and D. H. Boland, "The Trophic Classification of Lakes Using ERTS Multispectral Scanner Data," Proceedings of the American Society of Photogrammetry 41st Annual Meeting, pp. 393-414, 1975.

42. Rogers, R. H., et al., Automated Classification of Eutrophication of Inland Lakes from Spacecraft Data, Special Report, Bendix Aerospace Systems Division, Ann Arbor, MI, 1974.

43. Kritikos, H. and L. Yorinks, "Suspended Solids Analysis Using ERTS-A Data," Remote Sensing of Environment, Vol. 3, No. 1, pp. 69-78, 1974.

44. Rogers, R. H., N. J. Shak, and J. B. McKeon, "Computer Mapping of Water Quality in Saginaw Day with Landsat Digital Data," Proceedings of the American Society of Photogrammetry 42nd Annual Meeting, pp. 584-596, 1976.

45. Polcyn, F. C. and D. R. Lyzenga, "Updating Coastal and Navigational Charts using ERTS-1 Data," Third ERTS-1 Symposium, Vol. 1, pp. 1333-1346, 1974.

46. Polcyn, F. C. and D. R. Lyzenga, "Calculations of Water Depth from ERTS-MSS Data," Symposium on Significant Results Obtained from the Earth Resources Satellite, Vol. 2, pp. 1433-1442, 1973.

47. Ross, D. S., "Water Depth Estimation with ERTS-1 Imagery," Symposium on Significant Results Obtained from the Earth Resources Satellite, Vol. 2, pp. 1423-1432, 1973.

48. Aldrich, R. C., et al., Evaluation of ERTS-1 Data for Forest and Rangeland Surveys, USDA Forest Service Research Paper PSW-112, 1976.

49. Draeger, W. C., "Areal Extent of Snow in Forested Regions: A Practical Estimation Technique Using ERTS-1 Data," Proceedings of the 9th International Symposium on Remote Sensing of Environment, Vol. 2, pp. 333-339, 1974.

50. Barnes, J. C., The Application of ERTS Imagery to Mapping Snow Cover in the Western United States, Final Report, NAS-CR 137223, Environmental Research and Technology, Inc., 1973.

51. Galding, D. L., "Snow Cover and Melting Snow from ERTS Imagery," Canadian Surveyor, Vol. 28, No. 2, pp. 128-134, 1974.

52. Haefner, H., et al., "Application of Remote Sensing in Switzerland," Proceedings of the Tenth International Symposium on Remote Sensing of Environment, Vol. I, pp. 563-570, 1975.

53. Meier, M. F., Evaluation of ERTS Imagery for Mapping and Detection of Changes of Snow Cover on Land and on Glaciers, Progress Report NASA-CR-136870, U. S. Geological Survey, Tacoma, WA, 1974.

54. Wiesnet, D. R. and D. F. McGinnis, Jr., "Snow-Extent Mapping with Lake Ice Studies Using ERTS-1 MSS Together with NOAA-2 VHRR," Third ERTS-1 Symposium, Vol. 1, pp. 995-1009, 1974.

55. Klemas, V., D. Bartlett, and W. Philpot, "Coastal and Estuarine Studies with ERTS-1 and Skylab," Remote Sensing of Environment, Vol. 3, No. 3, pp. 153-174, 1974.

56. Klemas, V., et al., "Monitoring Coastal Water Properties and Current Circulation with ERTS-1," Third ERTS-1 Symposium, Vol. 1, pp. 1387-1441, 1974.

57. Dolan, R. and L. Vincent, "Evaluation of Land Use Mapping from ERTS in the Shore Zone of CARETS," Symposium on Significant Results Obtained from the Earth Resources Satellite, Vol. I, pp. 939-948, 1973.

58. Otterman, J., G. Ohring, and A. Ginzburg, "Results of the Israeli Multidisciplinary Data Analysis of ERTS-1 Imagery," Remote Sensing of Environment, Vol. 3, No. 2, pp. 133-148, 1974.

59. William R. S., "Coastal and Submarine Features on MSS Imagery of Southeastern Massachusetts: Comparison with Conventional Maps," Symposium on Significant Results Obtained from the Earth Resources Satellite, Vol. II, pp. 1413-1422, 1973.

60. Smith, V. E., "Thematic Mapping of Coral Reefs Using LANDSAT Data," Proceedings of the Tenth International Symposium on Remote Sensing of Environment, Vol. I, pp. 585-594, 1975.

61. Apel, J. R. and R. L. Charnell, "Ocean Internal Waves Off the North American and African Coasts from ERTS-1," Third Earth Resources Technology Satellite-1 Symposium, Vol. 1, 1973.

62. Maul, G. A., "Remote Sensing of Ocean Currents Using ERTS Imagery," Symposium on Significant Results Obtained from the Earth Resources Satellite, Vol. II, pp. 1365-1376, 1973.

63. Maul, G. A., Remote Sensing of Ocean Currents, NASA-CR-136808, National Oceanic and Atmospheric Administration, Miami, FL, 1974.

64. McKee, E. D., "The Study of Sand Seas on a Global Scene," Third ERTS-1 Symposium, 1975.

65. Williams, R. S., "Environmental Studies of Ireland with ERTS-1 Imagery," Proceedings of the 9th International Symposium on Remote Sensing of Environment, Vol. 1, pp. 31-81, 1974.

66. Gimbarzevsky, P., "Interpretation of ERTS Imagery in Biophysical Surveys," Canadian Surveyor, Vol. 28, No. 2, pp. 171-176, 1974.

67. Elberson, G. W. W., "Interpretation of ERTS-MSS Images of a Savanna Area in Eastern Columbia," Symposium on Significant Results Obtained from the Earth Resources Satellite, Vol. I, pp, 105-120, 1973.

68. Frazee, C. J., et al., "Use of ERTS-1 Imagery for Land Evaluation in Pennington County, South Dakota," Proceedings of the 9th International Symposium on Remote Sensing of Environment, Vol. 1, pp. 549-568, 1974.

69. Henderson, J. A., Jr., J. V. Gardner, and J. E. Cipra, "An Interpretation of a Geologic Map of Fannen County, Texas, Prepared by ADP Techniques from ERTS MSS Data," Remote Sensing of Earth Resources, Vol. 2, pp. 915-924.

70. Baumgardner, M. F. and J. A. Henderson, "Mapping Soils, Crops, and Rangelands by Machine Analysis of Multitemporal ERTS-1 Data," Third Earth Resources Technology Satellite-1 Symposium, Vol. 1, pp. 205-223, 1973.

71. Anderson, J. H., L. Shapiro, and A. E. Belon, "Vegetative and Geologic Mapping of the Western Seward Pennisula, Alaska Based on ERTS-1 Imagery," Symposium on Significant Results Obtained from the Earth Resources Satellite, Vol. I, pp. 67-76, 1973.

72. Carter, W. D., Evaluation of ERTS-1 Data Applications to Geologic Mapping, Structural Analysis and Mineral Resources Inventory of South America with Special Emphasis on the Andes Mountain Region, NASA-CR-137247, U. S. Geological Survey, Washington, D. C., 1973.

73. Masifield, P. M. and D. L. Laman, "Enhancement of Geologic Features Near Mojave, California by Spectral Band Ratioing of Landsat MSS Data," Proceedings of the Tenth International Symposium of Remote Sensing of Environment, pp. 1067-1071, 1975.

74. Vincent, R. K., Spectral Ratio Imaging Methods for Geological Remote Sensing from Aircraft and Satellite, Environmental Research Institute of Michigan, Ann Arbor, MI, 1973.

75. Haralick, R. M. and K. S. Shanmugan, "Combined Spectral and Spatial Processing of ERTS Imagery Data," Remote Sensing of Environment, Vol. 3, No. 1, pp. 3-13, 1974.

76. Schecter, R. N., "Resource Inventory Using LANDSAT Data for Areawide Water Quality Planning," Purdue: LARS Symposium Proceedings Remotely Sensed Data, pp. 1B-10, 1976.

77. Carter, V., J. McGinness, and R. Anderson, "Mapping Northern Atlantic Coastal Marshlands, Maryland-Virginia, Using ERTS Imagery," Remote Sensing of Earth Resources, Vol. 2, pp. 1011-1028, 1973.

78. Dodge, A. G. and E. S. Bryant, " Forest Type Mapping with Satellite Data," Journal of Forestry, Vol. 74, No. 8, pp. 526-531, 1976.